REPORT

OF THE

SIXTIETH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

LEEDS IN SEPTEMBER 1890.

LONDON:
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OBJECTS.

The Association contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis* : but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes :—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz. :—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members *who have not intermitted* their Annual Subscription.
2. *At reduced or Members' Price*, viz., two-thirds of the Publication Price. —Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]
3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s*. 6*d*. per volume.[1]

Application to be made at the Office of the Association.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

[1] A few complete sets, 1831 to 1874, are on sale, at £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.[1]

1. Delegates nominated by the Corresponding Societies under the conditions hereinafter explained. *Claims under this Rule to be sent to the Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organising Sectional Committees.[2]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organising Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[3] and of preparing Reports

[1] Revised by the General Committee, 1884.

[2] Passed by the General Committee, Edinburgh, 1871.

[3] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be read, are now as far as possible determined by Organising Committees for the several Sections *before the beginning of the Meeting.* It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the

thereon, and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first meeting. The Sectional Presidents of former years are *ex officio* members of the Organising Sectional Committees.[1]

An Organising Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to nominate the first members of the Sectional Committee, if they shall consider it expedient to do so, and to settle the terms of their report to the General Committee, after which their functions as an Organising Committee shall cease.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday at 2 P.M., on the following Thursday, Friday, Saturday,[4] Monday, and Tuesday, from 10 to 11 A.M., punctually, for the objects stated in the Rules of the Association, and specified below.

The business is to be conducted in the following manner:—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2. No paper shall be read until it has been formally accepted by the

several Communications, that each author should prepare an Abstract of his Memoir of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before........................., addressed to the General Secretaries, at the office of the Association. 'For Section.........' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. three complete weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Secretary, *before the conclusion of the Meeting.*

[1] Added by the General Committee, Sheffield, 1879.

[2] Revised by the General Committee, Swansea, 1880.

[3] Passed by the General Committee, Edinburgh, 1871.

[4] The meeting on Saturday was made optional by the General Committee at Southport, 1883.

Committee of the Section, and entered on the minutes accordingly.

3. Papers which have been reported on unfavourably by the Organising Committees shall not be brought before the Sectional Committees.[1]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Report. He will next proceed to read the Report of the Organising Committee.[2] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxvi), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association, and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and*

[1] These rules were adopted by the General Committee, Plymouth, 1877.

[2] This and the following sentence were added by the General Committee, Edinburgh, 1871.

one of them appointed to act as Chairman, who shall have notified personally or in writing his willingness to accept the office, the Chairman to have the responsibility of receiving and disbursing the grant (if any has been made) and securing the presentation of the Report in due time; and further, it is expedient that one of the members should be appointed to act as Secretary, for ensuring attention to business.

That it is desirable that the number of Members appointed to serve on a Committee should be as small as is consistent with its efficient working.

That a tabular list of the Committees appointed on the recommendation of each Section should be sent each year to the Recorders of the several Sections, to enable them to fill in the statement whether the several Committees appointed on the recommendation of their respective Sections had presented their reports.

That on the proposal to recommend the appointment of a Committee for a special object of science having been adopted by the Sectional Committee, the number of Members of such Committee be then fixed, but that the Members to serve on such Committee be nominated and selected by the Sectional Committee at a subsequent meeting.[1]

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such Report has been received.[2]

Notices regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Chairman of a Committee to whom a money grant has been made must (previously to the next Meeting of the Association) forward to the General Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one Meeting of the Association expire *a week before* the opening of the ensuing Meeting; nor is the Treasurer authorised, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General

[1] Revised by the General Committee, Bath, 1888.

[2] Passed by the General Committee at Sheffield, 1879.

Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Chairman is the only person entitled to call on the Treasurer, Professor A. W. Williamson, 17 Buckingham Street, London, W.C., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation from 10 to 11 daily. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At 11 precisely the Chair will be taken,[1] and the reading of communications, in the order previously made public, commenced. At 3 P.M. the Sections will close.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1. To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.
2. To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Secretary.
3. Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

[1] The sectional meetings on Saturday and on Wednesday may begin at any time which may be fixed by the Committee, not earlier than 10 or later than 11. Passed by the General Committee at Bath, 1888.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

Presidents of the Association in former years are *ex officio* members of the Committee of Recommendations.[1]

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

All proposals for establishing new Sections, or altering the titles of Sections, or for any other change in the constitutional forms and fundamental rules of the Association, shall be referred to the Committee of Recommendations for a report.[2]

Corresponding Societies.[3]

1. Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results.

2. Application may be made by any Society to be placed on the List of Corresponding Societies. Applications must be addressed to the Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the General Committee, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable.

4. Every Corresponding Society shall return each year, on or before the 1st of June, to the Secretary of the Association, a schedule, properly filled up, which will be issued by the Secretary of the Association, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.

5. There shall be inserted in the Annual Report of the Association a list, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognisance of one or other of the various Sections of the Association.

6. A Corresponding Society shall have the right to nominate any

[1] Passed by the General Committee at Newcastle, 1863.
[2] Passed by the General Committee at Birmingham, 1865.
[3] Passed by the General Committee, 1884.

one of its members, who is also a Member of the Association, as its delegate to the Annual Meeting of the Association, who shall be for the time a Member of the General Committee.

Conference of Delegates of Corresponding Societies.

7. The Conference of Delegates of Corresponding Societies is empowered to send recommendations to the Committee of Recommendations for their consideration, and for report to the General Committee.

8. The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually nominated by the Council, and appointed by the General Committee, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

9. The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the meetings.

10. The Secretaries of each Section shall be instructed to transmit to the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

11. It will be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they and others who take part in the meetings may be able to bring those recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

(1) The Council shall consist of [1]

1. The Trustees.
2. The past Presidents.
3. The President and Vice-Presidents for the time being.
4. The President and Vice-Presidents elect.
5. The past and present General Treasurers, General and Assistant General Secretaries.
6. The Local Treasurer and Secretaries for the ensuing Meeting.
7. Ordinary Members.

(2) The Ordinary Members shall be elected annually from the General Committee.

(3) There shall be not more than twenty-five Ordinary Members, of whom not more than twenty shall have served on the Council, as Ordinary Members, in the previous year.

(4) In order to carry out the foregoing rule, the following Ordinary Members of the outgoing Council shall at each annual election be ineligible for nomination:—1st, those who have served on the Council for the greatest number of consecutive years; and, 2nd, those who, being resident in or near London, have attended the fewest number of Meetings during the year —observing (as nearly as possible) the proportion of three by seniority to two by least attendance.

(5) The Council shall submit to the General Committee in their Annual Report the names of the Members of General Committee whom they recommend for election as Members of Council.

(6) The Election shall take place at the same time as that of the Officers of the Association.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

[1] Passed by the General Committee, Belfast, 1874.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Es
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.

SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society. HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford. CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT. ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.

The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hind, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S. F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.

PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S. L. & E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk His Grace the Duke of Richmond, K.G., P.C., D.C.L. His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. The Right Hon. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, M.Inst.C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S. L. & E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S. L. & E. Professor Allen Thomson, M.D., LL.D., F.R.S. L. & E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S. L. & E. PLYMOUTH, August 15 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S. L. & E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology. SWANSEA, August 25 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. Professor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.
ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.

The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., Ph.D., LL.D., F.R.S.L. & E., F.C.S. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau. Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. Thomas Sterry Hunt, Esq., M.A., D.Sc., LL.D., F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B., M.P., Ph.D., LL.D., F.R.S. L. & E., F.C.S. ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.G., D.C.L., Chancellor of the University of Aberdeen The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. James Matthews, Esq., Lord Provost of the City of Aberdeen Professor Sir William Thomson, M.A., LL.D., F.R.S. L. & E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S Professor G. Pirie, M.A.
SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire The Right Rev. the Lord Bishop of Worcester, D.D. Thomas Martineau, Esq., Mayor of Birmingham Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. Rev. A. R. Vardy, M.A. Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., PH.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E. BATH, September 5, 1888.	The Right Hon. the Earl of Cork and Orrery, Lord Lieutenant of Somerset The Most Hon. the Marquis of Bath The Right Hon. and Right Rev. the Lord Bishop of Bath and Wells, D.D. The Right Rev. the Bishop of Clifton, D.D. The Right Worshipful the Mayor of Bath The Right Worshipful the Mayor of Bristol Sir F. A. Abel, C.B., D.C.L., F.R.S., V.P.C.S. The Venerable the Archdeacon of Bath, M.A. The Rev. Leonard Blomefield, M.A., F.L.S., F.G.S. Professor Michael Foster, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S. W. S. Gore-Langton, Esq., J.P., D.L. H. D. Skrine, Esq., J.P., D.L. E. R. Wodehouse, Esq., M.P. Colonel R. P. Laurie, C.B., M.P. Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.
PROFESSOR WILLIAM HENRY FLOWER, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., Director of the Natural History Departments of the British Museum. NEWCASTLE-UPON-TYNE, September 11, 1889.	His Grace the Duke of Northumberland, K.G., D.C.L., LL.D., Lord Lieutenant of Northumberland The Right Hon. the Earl of Durham, Lord Lieutenant of Durham The Right Hon. the Earl of Ravensworth The Right Rev. the Lord Bishop of Newcastle, D.D. The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S. The Right Hon. John Morley, M.P., LL.D. The Very Rev. the Warden of the University of Durham, D.D. The Right Worshipful the Mayor of Newcastle The Worshipful the Mayor of Gateshead Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S., M.Inst.C.E. Sir Charles Mark Palmer, Bart., M.P.	Professor P. Phillips Bedson, D.Sc., F.C.S. Professor J. Herman Merivale, M.A.
SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L., D.Sc., F.R.S., P.P.C.S., Hon. M.Inst.C.E. LEEDS, September 3, 1890.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Most Hon. the Marquis of Ripon, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Sir Lyon Playfair, K.C.B., Ph.D., LL.D., M.P., F.R.S., F.C.S. The Right Hon. W. L. Jackson, M.P., F.S.S. The Right Worshipful the Mayor of Leeds Sir James Kitson, Bart., M.Inst.C.E., F.R.G.S. Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A., F.C.S. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc., F.C.S.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries

MATHEMATICAL AND PHYSICAL SCIENCES.

COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.

1832. Oxford......	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.

SECTION A.—MATHEMATICS AND PHYSICS.

1835. Dublin......	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol......	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S............	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.........	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.........	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.

Date and Place	Presidents	Secretaries
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford......	Rev. B. Price, M.A., F.R.S....	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter......	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S.	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol......	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin......	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.

Date and Place	Presidents	Secretaries
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1881. York.........	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Prof. O. J. Lodge, D. MacAlister, Rev. W. Routh.
1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal ...	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	C. Carpmael, W. M. Hicks, Prof. A. Johnson, Prof. O. J. Lodge, Dr. D. MacAlister.
1885. Aberdeen...	Prof. G. Chrystal, M.A., F.R.S.E.	R. E. Baynes, R. T. Glazebrook, Prof. W. M. Hicks, Prof. W. Ingram.
1886. Birmingham	Prof. G. H. Darwin, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. J. H. Poynting, W. N. Shaw.
1887. Manchester	Prof. Sir R. S. Ball, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. H. Lamb, W. N. Shaw.
1888. Bath.........	Prof. G. F. Fitzgerald, M.A., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw.
1889. Newcastle-upon-Tyne	Capt. W. de W. Abney, C.B., R.E., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. H. Stroud.
1890. Leeds	J. W. L. Glaisher, Sc.D., F.R.S., V.P.R.A.S.	R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. W. Stroud.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford......	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope..........................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.

Date and Place	Presidents	Secretaries
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. A. Miller, M.D., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E., F.C.S.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S., F.C.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S., F.C.S. ...	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S., F.C.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S.	H. S. Bell, W. Chandler Roberts, J. M. Thomson.

Date and Place	Presidents	Secretaries
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, Dr. W. R. Eaton Hodgkinson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.
1885. Aberdeen ...	Prof. H. E. Armstrong, Ph.D., F.R.S., Sec. C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, Dr. W. J. Simpson.
1886. Birmingham	W. Crookes, F.R.S., V.P.C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, W. W. J. Nicol, C. J. Woodward.
1887. Manchester	Dr. E. Schunck, F.R.S., F.C.S.	Prof. P. Phillips Bedson, H. Forster Morley, W. Thomson.
1888. Bath.........	Prof. W. A. Tilden, D.Sc., F.R.S., V.P.C.S.	Prof. H. B. Dixon, Dr. H. Forster Morley, R. E. Moyle, Dr. W. W J. Nicol.
1889. Newcastle-upon-Tyne	Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S.	Dr. H. Forster Morley, D. H. Nagel, Dr. W. W. J. Nicol, H. L. Pattinson, jun.
1890. Leeds	Prof. T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas. C.S.	C. H. Bothamley, Dr. H. Forster Morley, D. H. Nagel, Dr. W. W. J. Nicol.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geography*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Captain H. M. Denham, R.N.
1838. Newcastle...	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhoe.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.

Date and Place	Presidents	Secretaries
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham.—*Geography*, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull.........	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin......	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford......	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. D. C. L. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.

[1] At a meeting of the General Committee held in 1850, it was resolved 'That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section,"' for Presidents and Secretaries of which see page liv.

Date and Place	Presidents	Secretaries
1867. Dundee ...	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. Thomas Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S., F.G.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. Martin Duncan, M.B., F.R.S., F.G.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, LL.D., F.R.S., F.G.S.	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen ...	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.
1888. Bath.........	Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.	Prof. G. A. Lebour, W. Topley, W. W. Watts, H. B. Woodward.
1889. Newcastle-upon-Tyne	Prof. J. Geikie, LL.D., D.C.L., F.R.S., F.G.S.	Prof. G. A. Lebour, J. E. Marr, W. W. Watts, H. B. Woodward.
1890. Leeds	Prof. A. H. Green, M.A., F.R.S., F.G.S.	J. E. Bedford, Dr. F. H. Hatch, J. E. Marr, W. W. Watts.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham.....................	W. Yarrell, Prof. Burnett.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. liii.

SECTION D.—ZOOLOGY AND BOTANY.

Date and Place	Presidents	Secretaries
1835. Dublin	Dr. Allman	J. Curtis, Dr. Litton.
1836. Bristol	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool	W. S. MacLeay	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow	Sir W. J. Hooker, LL.D.	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork	William Thompson, F.L.S.	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S.	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. liii.]

Date and Place	Presidents	Secretaries
1848. Swansea	L. W. Dillwyn, F.R.S.	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool	Prof. Balfour, M.D., F.R.S.	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford	Rev. Prof. Henslow, F.L.S.	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S.	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.

Date and Place	Presidents	Secretaries
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.[1]

1866. Nottingham	Prof. Huxley, LL.D., F.R.S. —*Physiological Dep.*, Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.*, Alf. R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh .	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.
1874. Belfast	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres. R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, M.D., F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, M.D., F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.

[1] At a meeting of the General Committee in 1865, it was resolved:—'That the title of Section D be changed to Biology;' and 'That for the word "Subsection," in the rules for conducting the business of the Sections, the word "Department" be substituted.'

Date and Place	Presidents	Secretaries
1876. Glasgow ...	A. Russel Wallace, F.R.G.S., F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, M.A., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick, F.R.S.E.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, LL.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister, M.D.—*Dep. of Anthropol.*, Francis Galton, M.A., F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, M.D., F.R.S.—*Dep. of Anat. and Physiol.*, F. M. Balfour, M.A., F.R.S.—*Dep. of Anthropol.*, F. W. Rudler, F.G.S.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	Richard Owen, C.B., M.D., F.R.S.—*Dep. of Anthropol.*, Prof. W. H. Flower, LL.D., F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, M.D., F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.	Prof. A. Gamgee, M.D., F.R.S.—*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, M.A., F.L.S.—*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, M.A., F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport [1]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal [2]...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.
1885. Aberdeen ...	Prof. W. C. McIntosh, M.D., LL.D., F.R.S. L. & E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.
1886. Birmingham	W. Carruthers, Pres. L.S., F.R.S., F.G.S.	Prof. T. W. Bridge, W. Heape, Prof. W. Hillhouse, W. L. Sclater, Prof. H. Marshall Ward.
1887. Manchester	Prof. A. Newton, M.A., F.R.S., F.L.S., V.P.Z.S.	C. Bailey, F. E. Beddard, S. F. Harmer, W. Heape, W. L. Sclater, Prof. H. Marshall Ward.

[1] By direction of the General Committee at Southampton (1882) the Departments of Zoology and Botany and of Anatomy and Physiology were amalgamated.

[2] By authority of the General Committee, Anthropology was made a separate Section, for Presidents and Secretaries of which see p. lix.

Date and Place	Presidents	Secretaries
1888. Bath	W. T. Thiselton-Dyer, C.M.G., F.R.S., F.L.S.	F. E. Beddard, S. F. Harmer, Prof. H. Marshall Ward, W. Gardiner, Prof. W. D. Halliburton.
1889. Newcastle-upon-Tyne	Prof. J. S. Burdon Sanderson, M.A., M.D., F.R.S.	C. Bailey, F. E. Beddard, S. F. Harmer, Prof. T. Oliver, Prof. H. Marshall Ward.
1890. Leeds	Prof. A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.	S. F. Harmer, Prof. W. A. Herdman, Dr. S. J. Hickson, Prof. F. W. Oliver, H. Wager, Prof. H. Marshall Ward.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.

SECTION E.—PHYSIOLOGY.

1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.

[1] By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. l.). Section E, being then vacant, was assigned in 1851 to Geography.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof.G.Rolleston,M.D.,F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S. L. & E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D...............	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.........	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham.[1]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. xlvii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846.Southampton	Dr. Pritchard.....................	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull.........	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S.........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S.........	J.W.Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.

[1] *Vide* note on page li.

Date and Place	Presidents	Secretaries
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, Clements R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton ...	Francis Galton, F.R.S.........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. Oliphant Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B., F.R.S., F.R.G.S., F.R.A.S.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S. L.&E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J. S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.
1886. Birmingham	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1888. Bath.........	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sulivan, A. Silva White.
1890. Leeds	Lieut.-Col. Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.	A. Barker, John Coles, J. S. Keltie, A. Silva White.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

Date and Place	Presidents	Secretaries
1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

Date and Place	Presidents	Secretaries
1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S. ...	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

Date and Place	Presidents	Secretaries
1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin......	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford......	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath.........	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers...........	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant-Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	E. Macrory, F. Purdy, C. T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, F. P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres. S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D., M.R.I.A.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York.........	Rt. Hon. M. E. Grant-Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.
1884. Montreal ...	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen...	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham	J. B. Martin, M.A., F.S.S.	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D., V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes, Prof. J. E. C. Munro, G. H. Sargant.
1888. Bath.........	Rt. Hon. Lord Bramwell, LL.D., F.R.S.	Prof. F. Y. Edgeworth, T. H. Elliott, Prof. H. S. Foxwell, L. L. F. R. Price.
1889. Newcastle-upon-Tyne	Prof. F. Y. Edgeworth, M.A., F.S.S.	Rev. Dr. Cunningham, T. H. Elliott, F. B. Jevons, L. L. F. R. Price.

Date and Place	Presidents	Secretaries
1890. Leeds	Prof. A. Marshall, M.A., F.S.S.	W. A. Brigg, Rev. Dr. Cunningham, T. H. Elliott, Prof. J. E. C. Munro, L. L. F. R. Price.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.........	Rev. W. T. Kingsley.
1846. Southampton.	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S.........	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, C.E., F.R.S.	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool...	John Scott Russell, F.R.S. ...	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, jun., H. M. Jeffery.
1857. Dublin	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge	Wm. Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.

Date and Place	Presidents	Secretaries
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	James Abernethy, V.P. Inst. C.E., F.R.S.E.	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton.	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F. Churton, H. T. Wood.
1883. Southport	James Brunlees, F.R.S.E., Pres.Inst.C.E.	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P.Inst.C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.
1885. Aberdeen...	B. Baker, M.Inst.C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham	Sir J. N. Douglass, M.Inst. C.E.	C. W. Cooke, J. Kenward, W. B. Marshall, E. Rigg.
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.
1888. Bath.........	W. H. Preece, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, E. Rigg, P. K. Stothert.
1889. Newcastle-upon-Tyne	W. Anderson, M.Inst.C.E. ...	C. W. Cooke, W. B. Marshall, Hon. C. A. Parsons, E. Rigg.
1890. Leeds	Capt. A. Noble, C.B., F.R.S., F.R.A.S.	E. K. Clark, C. W. Cooke, W. B. Marshall, E. Rigg.

ANTHROPOLOGICAL SCIENCE.

SECTION H.—ANTHROPOLOGY.

1884. Montreal ...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.
1885. Aberdeen...	Francis Galton, M.A., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. A. Macgregor.
1886. Birmingham	Sir G. Campbell, K.C.S.I., M.P., D.C.L., F.R.G.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. R. Saundby.

Date and Place	Presidents	Secretaries
1887. Manchester	Prof. A. H. Sayce, M.A.	G. W. Bloxam, Dr. J. G. Garson, Dr. A. M. Paterson.
1888. Bath.........	Lieut.-General Pitt-Rivers, D.C.L., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, J. Harris Stone.
1889. Newcastle-upon-Tyne	Prof. Sir W. Turner, M.B., LL.D., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, Dr. R. Morison, Dr. R. Howden.
1890. Leeds	Dr. J. Evans, Treas.R.S., F.S.A., F.L.S., F.G.S.	G. W. Bloxam, Dr. C. M. Chadwick, Dr. J. G. Garson.

LIST OF EVENING LECTURES.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S......	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison.................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S.........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S............	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford......	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy,F.R.S.,Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent Discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent Discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.

Date and Place	Lecturer	Subject of Discourse
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Royal.	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S.	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.	The Balloon Ascents made for the British Association.
1864. Bath	Prof. Roscoe, F.R.S.	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S. ...	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.	Insular Floras.
1867. Dundee	Archibald Geikie, F.R.S.	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of Knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S.	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer F.R.S. ..	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool ...	Prof. J. Tyndall, LL.D., F.R.S.	Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S.	Some recent Investigations and Applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.

Date and Place	Lecturer	Subject of Discourse
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarised Light.
	F. J. Bramwell, F.R.S..........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The *Challenger* Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	The Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S............	The new Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S..........	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S.	The Electric Discharge, its Forms and its Functions.
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick, F.R.S.E.	Galvani and Animal Electricity.
1884. Montreal ...	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E..........	The Great Ocean Basins.
1886. Birmingham	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton, K.C.M.G.	Explorations in Central Africa.
1888. Bath.........	Prof. W. E. Ayrton, F.R.S. ...	The Electrical Transmission of Power.
	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
1889. Newcastle-upon-Tyne	Prof. W. C. Roberts-Austen, F.R.S.	The Hardening and Tempering of Steel.
	Walter Gardiner, M.A.........	How Plants maintain themselves in the Struggle for Existence.
1890. Leeds	E. B. Poulton, M.A., F.R.S....	Mimicry.
	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Discourse
1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool ..	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S............	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B., R.N.	A Journey through Africa.
1877. Plymouth...	W. H. Preece	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.
1882. Southampton.	John Evans, D.C.L., Treas. R.S.	Unwritten History, and how to read it.
1883. Southport	Sir F. J. Bramwell, F.R.S. ...	Talking by Electricity—Telephones.
1884. Montreal ...	Prof. R. S. Ball, F.R.S.........	Comets.
1885. Aberdeen ...	H. B. Dixon, M.A.	The Nature of Explosions.
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S.	Electric Lighting.
1888. Bath	Sir John Lubbock, Bart., M.P., F.R.S.	The Customs of Savage Races.
1889. Newcastle-upon-Tyne	B. Baker, M.Inst.C.E.	The Forth Bridge.
1890. Leeds	Prof. J. Perry, D.Sc., F.R.S.	Spinning Tops.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE LEEDS MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—J. W. L. Glaisher, D.Sc., F.R.S., V.P.R.A.S.

Vice-Presidents.—Professor Oliver J. Lodge, F.R.S.; Professor E. Mascart; Lord Rayleigh, Sec. R.S.; Professor H. A. Rowland, F.R.S.; Professor A. W. Rücker, F.R.S.; Sir Wm. Thomson, F.R.S.

Secretaries.—R. T. Glazebrook, F.R.S.; Professor A. Lodge, M.A.; W. N. Shaw, M.A. (*Recorder*); Professor W. Stroud, D.Sc.

SECTION B.—CHEMICAL SCIENCE.

President.—Professor T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas. C.S.

Vice-Presidents.—Professor P. Phillips Bedson, D.Sc.; Sir I. Lowthian Bell, Bart., F.R.S.; Professor H. B. Dixon, F.R.S.; Dr. J. H. Gladstone, F.R.S.; Professor G. D. Liveing, F.R.S.; Dr. W. H. Perkin, F.R.S.; Sir H. E. Roscoe, F.R.S.; Dr. E. Schunck, F.R.S.; Professor A. Smithells, B.Sc.

Secretaries.—C. H. Bothamley, F.C.S.; H. Forster Morley, D.Sc. (*Recorder*); D. H. Nagel, M.A.; Dr. W. W. J. Nicol, M.A.

SECTION C.—GEOLOGY.

President.—Professor A. H. Green, M.A., F.R.S., F.G.S.

Vice-Presidents.—Professor T. G. Bonney, F.R.S.; James W. Davis, F.G.S.; Professor T M'K. Hughes, F.R.S.; Professor O. C. Marsh; R. H. Tiddeman, M.A.; W. Topley, F.R.S.; Dr. H. Woodward, F.R.S.

Secretaries.—J. E. Bedford; F. H. Hatch, Ph.D.; J. E. Marr, M.A.; W. W. Watts, M.A. (*Recorder*).

SECTION D.—BIOLOGY.

President.—Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.

Vice-Presidents.—Professor F. O. Bower, F.R.S.E.; Francis Darwin, F.R.S.; Professor L. C. Miall, F.L.S.; Professor A. Newton, F.R.S.; Professor D. H. Scott, Ph.D.; Professor W. C. Williamson, F.R.S.

Secretaries.—S. F. Harmer, M.A.; Professor W. A. Herdman, D.Sc.; Sydney J. Hickson, D.Sc.; Professor F. W. Oliver, D.Sc.; Harold Wager; Professor H. Marshall Ward, F.R.S. (*Recorder*).

SECTION E.—GEOGRAPHY.

President.—Lieut.-Colonel Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.

Vice-Presidents.—Sir F. J. Goldsmid, K.C.S.I.; Admiral Sir E. Ommanney, C.B., F.R.S.; E. G. Ravenstein, F.R.G.S.

Secretaries.—A. Barker, M.A.; John Coles, F.R.G.S.; J. Scott Keltie, F.R.G.S. (*Recorder*); A. Silva White, F.R.S.E.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—Professor Alfred Marshall, M.A., F.S.S.

Vice-Presidents.—Charles Booth, F.S.S.; Professor F. Y. Edgeworth, D.C.L.; Professor H. S. Foxwell, F.S.S.; J. B. Martin, F.S.S.; Professor Sidgwick, F.S.S.

Secretaries.—W. A. Brigg, M.A.; Rev. W. Cunningham, D.D.; T. H. Elliott, F.S.S. (*Recorder*); Professor J. E. C. Munro, LL.D.; L. L. F. R. Price, M.A.

SECTION G.—MECHANICAL SCIENCE.

President.—Captain Andrew Noble, C.B., F.R.S., F.R.A.S.

Vice-Presidents.—G. F. Deacon, M.Inst.C.E.; Professor V. Dwelshauvers-Dery; Arthur Greenwood; L. F. Vernon Harcourt, M.Inst.C.E.; Sir James Kitson, Bart.; Benjamin Walker, M.Inst.C.E.

Secretaries.—E. K. Clark, B.A.; C. W. Cooke; W. Bayley Marshall, M.Inst.C.E.; Edward Rigg, M.A. (*Recorder*).

SECTION H.—ANTHROPOLOGY.

President.—John Evans, D.C.L., LL.D., D.Sc., Treas. R.S., Pres. S.A., F.L.S., F.G.S.[1]

Vice-Presidents.—Professor D. J. Cunningham, M.D.; F. W. Rudler, F.G.S.; Professor Flower, C.B., F.R.S.; Sir Rawson Rawson, K.C.M.G.

Secretaries.—G. W. Bloxam, M.A. (*Recorder*); Dr. C. M. Chadwick, M.A.; Dr. J. G. Garson.

[1] Dr. Evans was unable to attend the meeting.

THE BRITISH ASSOCIATION FOR

Dr. THE GENERAL TREASURER'S ACCOUNT

1889–90. RECEIPTS.

	£	s.	d.
Balance of account rendered at Newcastle Meeting	1052	5	0
By Life Compositions	300	0	0
,, New Annual Members	244	0	0
,, Subscriptions of Old Annual Members	665	0	0
,, Associates' Tickets at Newcastle Meeting	1021	0	0
,, Ladies' Tickets at Newcastle Meeting	579	0	0
,, Sale of Publications	62	9	6
,, Sale of Reports, by Mr. Murray, 1889–90	112	16	0
,, Rent received from Mathematical Society, for year ended September 29, 1889	12	15	0
,, Interest on Exchequer Bills	28	0	7
,, Dividends on Consols	227	18	4
,, Dividends on India 3 per cents.	105	6	0
,, Sale of Exchequer Bills (£1000)	999	0	10
,, Unexpended balance of Grant for Electrolysis	14	4	0
	£5423	15	3

Investments Account: September 1890.

	£	s.	d.
New Consols	8500	0	0
India 3 per cents.	3600	0	0
Exchequer Bills	500	0	0

THE ADVANCEMENT OF SCIENCE.

(not including receipts at the Leeds Meeting). *Cr.*

1889–90. PAYMENTS.

	£	s.	d.
To Expenses of Newcastle Meeting, including Printing and Advertising, &c.	249	12	6
,, Salaries, one year (1889–90)	675	0	0
,, Rent of Office, 22 Albemarle Street, W. (1889–90)	117	0	0
,, Spottiswoode & Co., for Printing Account (1888–89)	1089	1	0
,, ,, ,, (1889–90)	1089	3	10
,, Purchase of Exchequer Bills (£1000)	1005	5	3

GRANTS.

	£	s.	d.
Experiments with a Tow-net	4	3	9
Volcanic Phenomena of Japan	75	0	0
Cretaceous Polyzoa	10	0	0
Naples Zoological Station	100	0	0
Calculating Mathematical Tables	25	0	0
Zoology and Botany of West India Islands	100	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Committee	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Properties of Solutions	10	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Electro-optics	50	0	0
Corresponding Societies	20	0	0
Waves and Currents in Estuaries	100	0	0
Analysis of Iron and Steel	10	0	0
Electrical Standards	12	17	0
Excavations at Oldbury Hill	15	0	0
Recording Results of Water Analysis	4	1	0
Methods of Teaching Chemistry	10	0	0
Oxidation of Hydracids in Sunlight	15	0	0
Circulation of Underground Waters	5	0	0
Fossil Phyllopoda	10	0	0
Botanical Station at Peradeniya	25	0	0
Silent Discharge of Electricity	5	0	0
Pellian Equation Tables	15	0	0
Marine Biological Association	30	0	0
West India Islands (2)	100	0	0
Waves and Currents in Estuaries (2)	50	0	0
Lias Beds of Northamptonshire	25	0	0
Electrolysis	5	0	0
Geological Photographs	7	14	11

	£	s.	d.
Grants	899	16	8
By Balance at Bank of England, Western Branch	297	7	1
In hands of Assistant to General Treasurer	1	8	11
	£5423	15	3

ALEX. W. WILLIAMSON, *General Treasurer.*

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L.	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S.	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S.	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.......	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne ...	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S.	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne	The Duke of Northumberland	...	...
1839, Aug. 26 ...	Birmingham.........	The Rev. W. Vernon Harcourt	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton......	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D. ...	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.......	314	18
1848, Aug. 9 ...	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12 ...	Birmingham.........	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2 ...	Ipswich	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3 ...	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S. ...	194	33
1856, Aug. 6 ...	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds..................	Richard Owen, M.D., D.C.L....	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. the Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A. ...	286	21
1861, Sept. 4 ...	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1 ...	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6 ...	Birmingham.........	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18 ...	Exeter	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.......	314	39
1871, Aug. 2 ...	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14 ...	Brighton	Dr. W. B. Carpenter, F.R.S. ...	245	36
1873, Sept. 17 ...	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19 ...	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25 ...	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6 ...	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15 ...	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14 ...	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20 ...	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25 ...	Swansea	A. C. Ramsay, LL.D., F.R.S....	144	11
1881, Aug. 31 ...	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23 ...	Southampton	Dr. C. W. Siemens, F.R.S.......	178	17
1883, Sept. 19 ...	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27 ...	Montreal	Prof. Lord Rayleigh, F.R.S. ...	235	20
1885, Sept. 9 ...	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1 ...	Birmingham.........	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31 ...	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5 ...	Bath	Sir F. J. Bramwell, F.R.S.......	266	36
1889, Sept. 11 ...	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3 ...	Leeds..................	Sir F. A. Abel, C.B., F.R.S. ...	259	21

* Ladies were not admitted by purchased Tickets until 1843. † Tickets of Admission to Sections only.

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total			
...	...	...	...	...	353	....	....	1831
...	...	...	...	...	...	....	....	1832
...	...	...	...	...	900	....	....	1833
...	...	...	...	...	1298	....	£20 0 0	1834
...	...	...	...	...	...	....	167 0 0	1835
...	...	...	...	...	1350	....	435 0 0	1836
...	...	...	...	...	1840	....	922 12 6	1837
...	...	...	1100*	...	2400	....	932 2 2	1838
...	...	...	...	34	1438	....	1595 11 0	1839
...	...	...	...	40	1353	....	1546 16 4	1840
46	317	...	60*	...	891	....	1235 10 11	1841
75	376	33†	331*	28	1315	....	1449 17 8	1842
71	185	...	160	...	...	....	1565 10 2	1843
45	190	9†	260	...	...	....	981 12 8	1844
94	22	407	172	35	1079	....	831 9 9	1845
65	39	270	196	36	857	....	685 16 0	1846
197	40	495	203	53	1320	....	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 3 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1538 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	35	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	12	2437	2441 0 0	1417 0 11	1889
368	92	680	334	21	1775	1776 0 0	789 16 8	1890

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

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REPORT OF THE COUNCIL.

Report of the Council for the year 1889–90, *presented to the General Committee at Leeds, on Wednesday, September* 3, 1890.

The Council have received reports during the past year from the General Treasurer, and his account for the year will be laid before the General Committee this day.

Since the Meeting at Newcastle-upon-Tyne the Council have elected the following Foreign Men of Science Corresponding Members of the Association:—

Gobert, M. A., Brussels.
Gilson, Prof. G., Louvain.
Nansen, Dr. F., Christiania.
Packard, Prof. A. S., Providence, R.I.

The Council have nominated the Right Hon. the Earl Fitzwilliam, the Right Hon. Sir Lyon Playfair, the Right Hon. W. L. Jackson, Vice-Presidents for the Meeting at Leeds.

The Council had also resolved to nominate the late Sir Edward Baines to the same office, and heard with regret of his death in the early part of the present year.

An invitation for the year 1892 has been received from the city of Edinburgh.

The Council much regret that the state of Mr. Atchison's health has made it necessary for him to reside abroad since November. He has, however, been able to correct the proofs and to edit the Report. The General Officers have received assistance in carrying on the business of the Association during the past year from Professor Bonney and Mr. Griffith.

The Council appointed a Committee, consisting of the President and General Officers, the President Elect, and the past Presidents and General Officers, to consider the steps to be taken in connection with the appointment of Assistant General Secretary. Mr. Griffith having at the request of this Committee expressed his willingness to resume the office, it was proposed by the Committee that he should be invited to do so; the Council concur in the proposal of the Committee, and recommend accordingly that Mr. Griffith be appointed Assistant General Secretary.

Resolution referred to the Council for consideration and action if desirable:—

(A) 'That the two following papers be printed *in extenso* in the Report of the Association:—(1) Professor C. F. Bastable: "The Incidence and Effects of Import and Export Duties." (2) Rev. Dr. Cunningham: "The Comtist Criticism of Economic Science."'

The Council resolved that these papers should be printed *in extenso.*

(B) 'That the Council be recommended to urge upon the Government of India—

'(a) The desirability of procuring anthropometric measurements of a representative series of tribes and castes in the Punjab, Bombay, Madras, the Central Provinces, and Assam, it being understood that trained observers are already available.

'(b) Also that in the Enumerators' Schedule of the Census of 1891 provision should be made for recording not only the caste to which a man belongs, but also the endogamous and exogamous groups within the caste of which he is a member, it being believed that this was actually done in the last Census of the Punjab, that it will not add to the cost of the census, and that it will materially enhance its accuracy and scientific value.'

The Council having considered this question resolved to send the following letter to the Secretary of State for India in Council:—

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

22 Albemarle Street, London, W.
February 1890.

To the Secretary of State for India in Council.

My Lord,—The Council of the British Association beg leave to state for your Lordship's information that, at the recent Meeting of the Association at Newcastle-upon-Tyne, attention was drawn to the ethnographic and anthropometric researches undertaken in Northern India during the last five years, under the orders of the Government of Bengal. It is understood that an ethnographic survey, based upon the statistics collected in the census of 1881, of the traditions, customs, religion, and social relations of the various castes and tribes inhabiting the territories administered by the Lieutenant-Governor of Bengal, has been conducted on the lines laid down in 1874 by a committee of the Anthropological Institute of Great Britain and Ireland. At the same time anthropometric inquiries, on the system of measurement prescribed by Dr. Paul Topinard, of the School of Anthropology at Paris, have been made into the physical characteristics of nearly 6,000 persons, representing eighty-nine of the chief castes and tribes of Bengal, the North-West Provinces, Oudh, and the Punjab. The data collected in the course of these researches seem to the Council to possess considerable scientific interest, and they venture to submit for your Lordship's consideration their views as to the advantage of further inquiry of the same kind in other parts of India, and on the question in what manner and to what extent the Government of India can properly be asked to assist in furthering such researches.

2. Without some help from the Government it is clear that no private agency can hope to attain any considerable measure of success. The field is too large, and the variety of custom and language too great, for isolated unofficial workers to produce much impression. Such inquiries, moreover, in order to yield really valuable results, must apply to a series of castes and tribes numerous enough to allow of the comparative and statistical methods of investigation being applied on a tolerably large scale. It is only by following a peculiar custom through the various forms which it assumes in different social aggregates that a trustworthy conclusion can be arrived at concerning its probable origin. The complete executive organisation which the Government of India has at its disposal is admirably adapted, in respect of knowledge of the people, their languages, and their modes of thought, to observe and record facts which may prove to be of the highest scientific value, while the experience gained in Bengal seems to show that this can be done at comparatively trifling expense.

3. Among the various kinds of information collected in the course of the inquiries set on foot by the Bengal Government, special interest attaches to two classes of data: first, the physical measurements already referred to, and secondly, the lists of the exogamous and endogamous subdivisions[1] which are met with within the different tribes and castes. Physical characters are held by the highest anthropological authorities to be the best, if not the only true, tests of race affinity; while the character of the internal structure of tribes and castes has an important bearing

[1] By the term 'exogamous subdivision' is meant a group from within which its male members cannot take their wives; by that of 'endogamous subdivision,' a group from outside of which its male members cannot take their wives.

on those studies in the early history of the family and the growth of society which are associated with the names of McLennan, Morgan, Maine, and Lubbock. Owing to the influence of the caste system, which by restricting intermarriage tends to preserve distinctions of type, India offers a peculiarly favourable field for anthropometric research. The division of the people into a large number of separate social aggregates, each maintaining its own peculiar customs, seems to lead to the transmission of early usage in a comparatively unaltered form.

4. While fully recognising the value of the anthropometric inquiries already undertaken, the Council observe that they cover only a portion of Northern India, while provinces which promise to yield results of special interest remain at present wholly untouched. In order to obtain data upon which final conclusions might be based, it would be desirable to collect similar measurements for selected castes and tribes in Madras, Bombay, the Central Provinces, and Assam, and at the same time to undertake in the Punjab a larger series of observations than have hitherto been made. The Council understand that the services of the trained measurers who took the Bengal observations might, under similar conditions, be again available; and they are advised that the cost of employing them for the period necessary to complete the work would not exceed 10,000 rupees. Mr. Risley, who conducted the Bengal inquiries, is willing to direct and supervise the operations in India, and to prepare the results for publication in any form that may be thought suitable. The Council accordingly express a hope that your Lordship may be moved to commend this proposal to the favourable consideration of the Government of India.

5. As regards the exogamous and endogamous subdivisions of tribes and castes, the Council venture to suggest that the approaching census of India offers an admirable opportunity for collecting lists of these without incurring unreasonable expenditure. It is understood that the enumerator's schedule will in any case contain a column in which the caste of every individual is entered, and it would appear that the addition of columns showing the exogamous and endogamous groups would not add materially to the cost of the operations. The information thus obtained would have great scientific value, while it would further tend to enhance the accuracy of the census itself. The Council are informed that in the last census of Bengal a large number of persons when asked for their caste-name gave instead the name of the exogamous or endogamous group to which they belonged, and that in most cases it was found impossible to assign these persons to any particular caste. By extending the range of inquiry in the manner suggested, this source of error would be eliminated.

6. In conclusion, if it should not be considered advisable to make a complete religious census, the Council would suggest that in the course of the house-census which precedes the actual enumeration it should be ascertained by what sect each of the existing temples is used. Statistics illustrating this point would throw much light on the development of the various forms of Brahminism, and would be a valuable contribution to the history of religion in the East.

We have the honour to be,
Your Lordship's most obedient Servants,
W. H. FLOWER, *President*.
DOUGLAS GALTON, } *General Secretaries.*
A. VERNON HARCOURT, }

To this letter the following reply has been received:—

India Office, Whitehall, S.W.
March 31, 1890.

Sir,—I am directed by the Secretary of State for India in Council to acknowledge the receipt of your letter of the 26th ultimo, in which, with reference to the valuable ethnographical researches of Mr. H. H. Risley in Bengal, it is suggested that similar anthropometric data should be collected in other parts of India, and that advantage should also be taken of the approaching census to ascertain the exogamous and endogamous groups to which the members of the different tribes and castes of the people of India belong.

In reply, I am to inform you that his Lordship in Council has been much interested in the proposals made by you on behalf of the British Association, which are of great value as indicating the course ethnographical investigations should take in India, and a copy of your letter has been forwarded to the Government of India.

I am to add that Viscount Cross has read with satisfaction the testimony your letter bears to the scientific character and importance of Mr. Risley's work in Northern India.

I am, Sir, your obedient Servant,
A. GODLEY.

Professor W. H. FLOWER, C.B., D.C.L., F.R.S., &c., &c.,
President, British Association for the Advancement of Science,
22 Albemarle Street, W.

India Office, Whitehall, S.W.
August 15, 1890.

Sir,—In continuation of my letter of March 31 last (R. & S. 264/90) I am directed by the Secretary of State for India in Council to forward herewith a copy of a letter, with its inclosure, from the Government of India on the subject of the proposals made by you on behalf of the British Association, that the ethnographic and anthropometric researches recently undertaken in Northern India should be extended to other parts of India, and that advantage should be taken of the approaching census of India for recording the exogamous and endogamous groups into which the different castes and tribes are divided.

I am, Sir, your obedient Servant,
A. GODLEY.

Professor W. H. FLOWER, C.B., D.C.L., F.R.S.,
President, British Association for the Advancement of Science,
22 Albemarle Street, W.

GOVERNMENT OF INDIA—HOME DEPARTMENT.

To the Right Honourable Viscount CROSS, G.C.B.,
Her Majesty's Secretary of State for India.

Simla, July 15, 1890.

My Lord,—We have the honour to acknowledge the receipt of your Lordship's Despatch No. 31 (Statistics), dated April 3, 1890, forwarding a copy of a letter from the President of the British Association for the Advancement of Science, in which, with reference to the ethnographic researches undertaken by Mr. H. H. Risley in Bengal, it is suggested that similar anthropometric data should be collected in other parts of India, and that advantage should be taken of the approaching census to ascertain the exogamous and endogamous groups to which the members of the different tribes and castes of the population belong.

2. We need not assure your Lordship that any proposals upon these subjects to which the British Association has lent the weight of its authority will receive our very careful consideration. We observe that the Council considers that the data collected by Mr. Risley possess considerable scientific interest, but we have ourselves not yet been able to form an opinion as to the merits of his work, as we have not yet received from him the volumes recording the results of his researches. These we do not expect to receive till after Mr. Risley's return from furlough in England at the end of November next. We shall then consider the question whether his investigations can usefully be supplemented in other parts of India.

3. We are of opinion that it would be quite impracticable for the enumerators who will be employed in filling in the census returns to undertake the task of collecting data as to endogamy and exogamy. The work involved in the preparation of the schedule which we have sanctioned will sufficiently tax the energy and intelligence of the enumerators, who, it must be remembered, will for the most part be men of little education, and any addition to it would greatly increase the risk of inaccuracy in the statistics generally. We think, however, that it will be possible, after the different castes and subdivisions of castes have been fully enumerated, to ascertain by local inquiry their relations as regards endogamy and exogamy. Such an inquiry can be undertaken at leisure, either when the census results are being compiled for each Province, or later, when the Local Govermnent or Administration is able to provide some specially qualified agency for the purpose.

Your Lordship will observe from the form of schedule prescribed for the enumerators at the census that we have already determined to make a complete religious census as far as possible, but we do not think that the results of ascertaining, as proposed by the British Association, what sect uses each of the existing temples would be of much scientific value, as vast numbers of Hindoos are eclectic and worship in numerous temples of different gods indifferently.

We have the honour to be, my Lord,

Your Lordship's most obedient, humble Servants,

LANSDOWNE. A. R. SCOBLE.
F. S. ROBERTS. C. A. ELLIOTT.
G. CHESNEY. P. P. HUTCHINS.
D. BARBOUR.

THE SCHEDULE CONTAINS APPENDIX A.

A. Standard Schedule. B. Standard Enumerator's Abstract.
C. Standard Block List. D. Instructions to Enumerators.

(C) 'That the Council of the Association be requested to consider the following Resolutions of the Committee of Section H, and, if approved, to bring them under the notice of H.M. Civil Service Commissioners and of the chief authorities of the Army, Navy, and Indian Civil Service Department :—

'(*a*) That the Committee concur in the opinion of H.M. Civil Service Commissioners (Report xxxiii. p. 15) that there is no especial difficulty in assigning marks for physical qualifications with adequate precision.

'(*b*) They urge that it is reasonable to include marks for physical qualifications among those by which the place of a candidate is determined in competitive examinations for posts where high physical efficiency is advantageous.'

The Council considered this question and resolved to address the following letter to the Civil Service Commissioners, the Secretaries of State for India and for War, and the Lords of the Admiralty :—

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

22 Albemarle Street, London, W.
March 1890.

The Council of the British Association for the Advancement of Science desire to submit the opinion expressed by the Anthropological Section of the Association last year, and subsequently confirmed by a Committee appointed by the Council, of the feasibility of assigning trustworthy marks for physical qualifications, and briefly to state some of the reasons for that opinion.

They feel it to be unnecessary to dwell on the desirability of including such marks in the examinations for entrance into services where high physical powers are important, but would merely allude to the fact that it was fully recognised by the War Office in 1878, at which time a Joint Committee of the War Office and of the Civil Service Commissioners was appointed to inquire into the question 'whether the present literary examinations for the army should be supplemented by physical competition.' Also that it was agreed to almost unanimously by the various speakers in the House of Lords in connection with that report, on May 21 and June 7, 1878, and on February 28, 1879. (See 'Hansard' for those dates, pp. 352, 1328, 1941.) The report was presented June 28, 1878.

The recommendations of the Joint Committee referred almost wholly to marks to be assigned for athletic performance. Objections to this method of examination were, however, pointed out by some of the witnesses; they were appreciated by the responsible authorities, and were strongly insisted upon by them in the concluding debate. These objections applied principally to the costliness of the necessary preparation, to the difficulty of conducting the tests, to the additional strain they would impose on the already severely taxed energies of the candidates, and to the interference of physical training with due preparation for the literary examinations. The consequence was that the recommendations of the Committee were not adopted by the responsible authorities, and the subject was laid aside.

The Council of the British Association now desire to point out that, in the opinion of anthropologists, athletic performance is by no means the only basis upon which trustworthy marks for physical qualifications may be assigned.

This opinion is confirmed by some experiments made at Eton College, of which an account was submitted to the British Association. Thirty-two youths, most of whom were candidates for the army, were inspected and marked by two medical men, sitting in separate rooms. The medical men had previously received the same general instructions, but otherwise acted independently. The marks they severally assigned to the youths were afterwards found to agree with considerable precision. Then, nineteen of these youths were set to write an English essay, and their performances in that respect were submitted to two examiners in turn, to be marked independently by them. The marks given by these examiners agreed together only one-half as closely as those given by the medical men. No one disputes the substantial trustworthiness of such literary examinations as these, however much they may be thought capable of improvement. But this experiment (so far as it goes) proves that the trustworthiness of physical examinations would be still greater.

The difficulty of formulating a system for the use of inspectors, according to which marks should be assigned on a common and easily understood principle, is greatly lessened by the use of anthropometric tests. Much experience testifies to the quickness and adequate precision with which the chief elements of physical efficiency admit of being measured. These are the breathing capacity and the strength, both of them to be regarded with reference to the stature and to the weight; the rapidity of muscular action; the quickness of response to a signal made either to the eye or to the ear; the keenness of eyesight, and that of hearing, and whether the colour-sense is normal or not.

An experiment made at Marlborough College, which has just been published, shows how small may be the differences between the class-places determined by these measures and those determined partly, in some cases, by the physical aspect, but principally by proficiency in the various school games, or, in other words, by athletic competition. Seventeen youths were measured by such apparatus as was then available at the College, and copies of their measures were distributed among the masters, to be marked by them on whatever principle they severally thought best. The individual results proved to be very discordant, but their averages, which express the result of the aggregate common sense of all the masters, ranked the boys in closely the same order as that independently assigned to them according to their proficiency in the various school games and to their apparent physique. It will be observed that if the masters had previously conferred and come to a mutual understanding on the principle according to which the marks should be assigned, they must necessarily have arrived at identical results, as they had definite and identical data to work upon. There happened to be one case of failure, which was instructive. This was due to the absence of any test at the College for rapidity of muscular action, or of promptness of response to a signal. The consequence was that an agile youth was rated too low.

The Council would point out that the experience gained by the measurement of about 2,000 students at Cambridge conclusively proves that success in literary examinations is in no manner connected with stature, weight, strength, or breathing capacity, and but slightly with keenness of eyesight. Such differences as there appear to be in these respects between the men who obtain high honours and those who take an ordinary degree are small, and can be accounted for. Successful literary men have probably great nervous energy, perseverance, and great power of concentrating their efforts, which would cause them to utilise such physical powers as they possessed with much effect, but they are shown to be neither superior nor inferior in the above-mentioned particulars to those who fail.

The Council of the British Association have noted with pleasure the opinion expressed by the Civil Service Commissioners in their Report of 1889 (xxxiii. p. 15), to the effect that they anticipate no greater difficulty in ranking candidates according to their physical than according to their literary qualifications. The Council thereupon beg to express the views at which they themselves have arrived as follow:—

It seems to them that the paucity of available data makes it scarcely possible at the present moment to elaborate as complete a system of assigning marks for physical qualifications as is desirable, and as, in their opinion, would be otherwise feasible. They therefore think it very important that suitable steps should be taken to obtain these data. For instance, if a temporary system of marks were tried, with the avowed determination of reconsidering the subject after some experience had been gained, the desired information would rapidly accumulate in the hands of the inspectors; the attention of schoolmasters would be strongly aroused, and it is probable that they would attempt a variety of experiments analogous to those alluded to at Eton and Marlborough, but on a much larger scale. In a very few years it might then become feasible to arrange a system that should be generally acceptable.

In furtherance of these views the Council of the British Association beg to submit the following recommendations:—

(1) That an inquiry should be held as to the best system of assigning marks for physical qualifications, on the double basis of inspection and anthropometry, with a view to its early establishment as a temporary and tentative system.

(2) That the marks to be given under this temporary system should be small, so as to affect the success of those candidates only who would be ranked by the present examinations very near to the dividing line between success and failure, and whose intellectual performances would consequently be nearly on a par, though they would differ widely in their physical qualifications.

(3) That determination should be expressed to reconsider the entire question after the experience of a few years.

The following replies have been received:—

Civil Service Commission, Westminster.
March 28, 1890.

Sir,—I am directed by the Civil Service Commissioners to acknowledge the receipt of your letter of the 25th instant transmitting a statement in regard to the feasibility of assigning marks for physical qualifications in the examinations for entrance into service where physical powers are important; and, in reply, I am to request that you will be good enough to convey to the Council of the British Association the thanks of the Commissioners for the communication, and to state that the Commissioners have the matter under consideration.

I have the honour to be, Sir, your obedient Servant,
E. HUMPHREYS.

The PRESIDENT,
British Association for the Advancement of Science.

India Office, Whitehall, S.W.
April 19, 1890.

Sir,—I am directed by the Secretary of State for India in Council to acknowledge the receipt of the letter signed by you and by the General Secretaries of the British Assoc ation for the Advancement of Science, dated the 25th ultimo, enclosing a statement in regard to the feasibility of assigning marks for physical qualifications in the examinations for entrance into services where physical powers are important.

In reply I am desired to state that Viscount Cross is already in communication with the Civil Service Commissioners with reference to the question of making physical qualifications an element in the competitions for the Civil Service of India.

I am, Sir, your obedient Servant,
JOHN E. GORST.

Professor W. H. FLOWER, C.B.,
President of the British Association for the Advancement of Science,
22 Albemarle Street, W.

War Office, April 24, 1890.

Sir,—I am directed by the Secretary of State for War to acknowledge the receipt of your letter of the 25th ultimo enclosing a statement in regard to the feasibility of assigning marks for physical qualifications in the examinations for entrance into services where physical powers are important.

The subject has received the consideration of His Royal Highness the Commander-in-Chief, and of the Secretary of State for War, who concur in the opinion that, with regard to the army, it is not desirable to depart from the existing system, which exacts from all candidates a certain standard of general health and physical fitness, leaving the competitive result to be determined by educational tests.

I have the honour to be, Sir, your obedient Servant,
RALPH THOMPSON.

The PRESIDENT,
British Association for the Advancement of Science.

The Council have been informed that a proposal to reappoint the Committee on a Uniform Nomenclature for the Fundamental Units of

Mechanics was intended to have been brought before the General Committee at Newcastle, and have resolved to recommend that the Report which has been drawn up by the members of the proposed Committee be received and published among the Reports.[1]

The report of the Corresponding Societies Committee has been received, and is now presented to the General Committee.

The Corresponding Societies Committee, consisting of Mr. Francis Galton, Professor R. Meldola (Secretary), Professor A. W. Williamson, Sir Douglas Galton, Professor Boyd Dawkins, Sir Rawson Rawson, Dr. J. G. Garson, Dr. J. Evans, Mr. J. Hopkinson, Mr. W. Whitaker, Mr. G. J. Symons, General Pitt-Rivers, Mr. W. Topley, and Professor T. G. Bonney, is hereby nominated for reappointment by the General Committee.

The Council nominate Mr. G. J. Symons, F.R.S., Chairman, Professor T. G. Bonney, F.R.S., Vice-Chairman, and Professor R. Meldola, F.R.S., Secretary to the Conference of Delegates of Corresponding Societies to be held during the meeting at Leeds.

At the request of the Council of the Australasian Association for the Advancement of Science papers relating to the meeting of this Association, which is appointed to take place at Christchurch, New Zealand, commencing on January 15, 1891, have been placed in the Reception Room. Members of the British Association are invited to attend the meeting at Christchurch, and the facilities offered by Shipping Companies and by the Railway Commissioners in New Zealand are described in detail in the papers.

The lease of the office of the Association, 22 Albemarle Street, London, W., will expire next year, and the Council, having ascertained that certain rooms in Burlington House were unoccupied, made an application to the Lords Commissioners of Her Majesty's Treasury for the use of these rooms. The Council are glad to report that the request has been granted under favourable conditions. The Council believe that a sum not exceeding 150*l.* will suffice for fitting and furnishing the rooms.

In accordance with the regulations the five retiring Members of the Council will be:—

Sir R. S. Ball.
Dr. A. Gamgee.
Prof. Ray Lankester.
Prof. H. M'Leod.
Admiral Sir E. Ommanney.

The Council recommend the re-election of the other ordinary Members of Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list:—

Ayrton, Prof. W. E., F.R.S.
Baker, Sir B., K.C.M.G., F.R.S.
Blanford, W. T., Esq., F.R.S.
Crookes, W., Esq., F.R.S.
Darwin, Prof. G. H., F.R.S.
Douglass, Sir J. N., F.R.S.
Evans, Dr. J., F.R.S.
Fitzgerald, Prof. G. F., F.R.S.
Geikie, Dr. A., F.R.S.
*Glazebrook, R. T., Esq., F.R.S.
Judd, Prof. J. W., F.R.S.
Liveing, Prof. G.D., F.R.S.
Martin, J. B., Esq., F.S.S.
Preece, W. H., Esq., F.R.S.
*Reinold, Prof. A. W., F.R.S.
Roberts-Austen, Prof. W. C., C.B., F.R.S.
Rücker, Prof. A. W., F.R.S.
Schäfer, Prof. E. A., F.R.S.
Schuster, Prof. A., F.R.S.
Sidgwick, Prof. H., M.A.
Thorpe, Prof. T. E., F.R.S.
*Ward, Prof. Marshall, F.R.S.
*Wharton, Capt. W. J. L., R.N., F.R.S.
*Whitaker, W., Esq., F.R.S.
Woodward, Dr. H., F.R.S.

[1] The Committee was finally unable to agree to a Report

Committees appointed by the General Committee at the Leeds Meeting in September 1890.

1. *Receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee	Grants
		£
The Volcanic and Seismological Phenomena of Japan.	*Chairman.*—Sir W. Thomson. *Secretary.*—Professor J. Milne. Professor W. G. Adams, Mr. J. T. Bottomley, and Professor A. H. Green.	10
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements.	*Chairman.*—Professor Carey Foster. *Secretary.*—Mr. R. T. Glazebrook. Sir William Thomson, Professors Ayrton, J. Perry, W. G. Adams, and Lord Rayleigh, Drs. O. J. Lodge, John Hopkinson, and A. Muirhead, Messrs. W. H. Preece and Herbert Taylor, Professors Everett and Schuster, Dr. J. A. Fleming, Professors G. F. Fitzgerald and Chrystal, Mr. H. Tomlinson, Professors W. Garnett and J. J. Thomson, Messrs. W. N. Shaw, J. T. Bottomley, and T. C. Fitzpatrick, and Professor J. Viriamu Jones.	100
Coöperating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.	*Chairman.*—Lord McLaren. *Secretary.*—Professor Crum Brown. Messrs. Milne-Home, John Murray, and Buchan, and Hon. R. Abercromby.	50
Considering the subject of Electrolysis in its Physical and Chemical Bearings.	*Chairman.*—Professor Fitzgerald. *Secretaries.*—Professors Armstrong and O. J. Lodge. Professors Sir William Thomson, Lord Rayleigh, J. J. Thomson, Schuster, Poynting, Crum Brown, Ramsay, Frankland, Tilden, Hartley, S. P. Thompson, M'Leod, Roberts-Austen, Rücker, Reinold, Carey Foster, and H. B. Dixon, Captain Abney, Drs. Gladstone, Hopkinson, and Fleming, and Messrs. Crookes, Shelford Bidwell, W. N. Shaw, J. Larmor, J. T. Bottomley, R. T. Glazebrook, J. Brown, E. J. Love, and John M. Thomson.	5

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£
The Application of Photography to the Elucidation of Meteorological Phenomena.	*Chairman.*—Mr. G. J. Symons. *Secretary.*—Mr. Clayden. Professor Meldola and Mr. John Hopkinson.	5
To investigate the Phenomena accompanying the Discharge of Electricity from Points.	*Chairman.*—Professor O. J. Lodge. *Secretary.*—Mr. A. P. Chattock. Professor Carey Foster.	10
To coöperate with Dr. Piazzi Smyth in his Researches on the Ultra Violet Rays of the Solar Spectrum.	*Chairman.*—Professor Liveing. *Secretary.*—Dr. Piazzi Smyth. Professors Dewar and Schuster.	50
Seasonal Variations in the Temperatures of Lakes, Rivers, and Estuaries in various parts of the United Kingdom in coöperation with the Local Societies represented on the Association.	*Chairman.*—Mr. John Murray. *Secretary.*—Dr. H. R. Mill. Professor Chrystal, Dr. A. Buchan, the Rev. C. J. Steward, the Hon. R. Abercromby, Mr. J. Y. Buchanan, Mr. David Cunningham, Mr. Isaac Roberts, Professor Fitzgerald, Dr. Sorby, and Mr. Willis Bund.	20
To consider the best Method of establishing an International Standard for the Analysis of Iron and Steel.	*Chairman.*—Professor Roberts-Austen. *Secretary.*—Mr. Thomas Turner. Sir F. Abel, Messrs. E. Riley and J. Spiller, Professor Langley, Mr. G. J. Snelus, and Professor Tilden.	10
Isomeric Naphthalene Derivatives	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Professor H. E. Armstrong.	25
The Investigation of the direct Formation of Haloid Salts from pure Materials.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Mr. W. A. Shenstone. Professor W. R. Dunstan and Mr. C. H. Bothamley.	25
The Action of Light upon dyed Colours.	*Chairman.*—Professor Thorpe. *Secretary.*—Professor J. J. Hummel. Dr. Perkin, Professor Russell, Captain Abney, and Professor Stroud.	20
Recording the Position, Height above the Sea, Lithological Characters, Size, and Origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation.	*Chairman.*—Professor J. Prestwich. *Secretary.*—Dr. H. W. Crosskey. Professors W. Boyd Dawkins, T. McK. Hughes, and T. G. Bonney and Messrs. C. E. De Rance, W. Pengelly, J. Plant, and R. H. Tiddeman.	10

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£
The Description and Illustration of the Fossil Phyllopoda of the Palæozoic Rocks.	*Chairman.*—Mr. R. Etheridge. *Secretary.*—Professor T. R. Jones. Dr. H. Woodward.	10
Carrying on the 'Geological Record.'	*Chairman.*—Mr. W. Whitaker. *Secretaries.*—Messrs. W. Topley and C. Davies Sherborne. Dr. G. J. Hinde, Messrs. E. T. Newton, R. B. Newton, F. W. Rudler, and J. J. H. Teall, and Professor Green.	100
The Collection, Preservation, and Systematic Registration of Photographs of Geological interest.	*Chairman.*—Professor J. Geikie. *Secretary.*—Mr. O. W. Jeffs. Professors Bonney, Boyd Dawkins, and V. Ball, Dr. T. Anderson, and Messrs. A. S. Reid, W. Gray, H. B. Woodward, J. E. Bedford, R. Kidston, W. W. Watts, J. W. Davis, and R. H. Tiddeman.	10
To work the very fossiliferous Transition Bed between the Middle and UpperLias in Northamptonshire, in order to obtain a full series of Upper Liassic Gasteropods and fix the horizon of a fine collection of Liassic Fish.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. Beeby Thompson. Messrs. W. D. Crick, T. G. George, W. Hull, E. A. Walford, E. Wilson, and H. B. Woodward.	25
To consider the best Methods for the Registration of all Type Specimens of Fossils in the British Isles, and to report on the same.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. A. Smith Woodward. Messrs. R. Etheridge, the Rev. G. F. Whidborne, R. Kidston, J. E. Marr, and C. Davies Sherborne.	10
The Volcanic Phenomena of Vesuvius and its neighbourhood.	*Chairman.*—Mr. H. Bauerman. *Secretary.*—Dr. H. J. Johnston-Lavis. Messrs. F. W. Rudler and J. J. H. Teall.	10
The Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Waters supplied to various Towns and Districts from these Formations.	*Chairman.*—Professor E. Hull. *Secretary.*—Mr. C. E. De Rance. Dr. H. W. Crosskey, Sir D. Galton, Professors G. A. Lebour and J. Prestwich, and Messrs. J. Glaisher, E. B. Marten, G. H. Morton, J. Parker, W. Pengelly, J. Plant, I. Roberts, C. Fox - Strangways, T. S. Stooke, G. J. Symons, W. Topley, Tylden-Wright, E. Wethered, and W. Whitaker.	5
To complete the Investigation of the Cave at Elbolton, near Skipton, in order to ascertain whether the remains of Palæolithic Man occur in the Lower Cave Earth.	*Chairman.*—Mr. J. W. Davis. *Secretary.*—Rev. E. Jones. Drs. J. Evans and J. G. Garson and Messrs. W. Pengelly, R. H. Tiddeman, and J. J. Wilkinson.	25

1. *Receiving Grants of Money*—continued.

Subject of Investigation or Purpose	Members of the Committee	Grant
		£
To arrange for the Occupation of a Table at the Laboratory of the Marine Biological Association at Plymouth.	*Chairman.*—Professor Flower. *Secretary.*—Mr. S. F. Harmer. Professors M. Foster, E. Ray Lankester, and S. H. Vines.	30
For taking steps to establish a Botanical Station at Peradeniya, Ceylon.	*Chairman.*—Professor M. Foster. *Secretary.*—Professor F. O. Bower. Professor Bayley Balfour, Mr. Thiselton-Dyer, Dr. Trimen, Professor Marshall Ward, Mr. Carruthers, Professor Hartog, and Mr. W. Gardiner.	50
For improving and experimenting with a Deep-sea Tow-net for opening and closing under water.	*Chairman.*—Professor A. C. Haddon. *Secretary.*—Mr. W. E. Hoyle. Professor W. A. Herdman.	40
Disappearance of Native Plants from their Local Habitats.	*Chairman.*—Mr. A. W. Wills. *Secretary.*—Professor W. Hillhouse. Messrs. E. W. Badger and George Claridge Druce.	5
To report on the present state of our Knowledge of the Zoology of the Sandwich Islands, and to take steps to investigate ascertained deficiencies in the Fauna.	*Chairman.*—Professor Flower. *Secretary.*—Dr. David Sharp. Dr. Blanford, Dr. Hickson, Professor Newton, Mr. Salvin, and Dr. Sclater.	100
To report on the present state of our Knowledge of the Zoology and Botany of the West India Islands, and to take steps to investigate ascertained deficiencies in the Fauna and Flora.	*Chairman.*—Professor Flower. *Secretary.*—Mr. D. Morris. Mr. Carruthers, Drs. Günther and Sclater, Mr. Thiselton- Dyer, Dr Sharp, Mr. F. Du Cane Godman, Professor Newton, and Colonel Feilden.	100
The Geography and the Habits, Customs, and Physical Characters of the Nomad Tribes of Asia Minor and Northern Persia, and to excavate on sites of Ancient Occupation.	*Chairman.*—Dr. Garson. *Secretary.*—Mr. Bent. Messrs. H. W. Bates, Bloxam, and J. Stuart Glennie, Sir Frederic Goldsmid, and Messrs. Pengelly and Rudler.	30
The Action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models.	*Chairman.*—Sir J. N. Douglass. *Secretary.*—Professor Osborne Reynolds. Professor Unwin and Messrs. W. Topley, E. Leader Williams, W. Shelford, G. F. Deacon, A. R. Hunt, W. H. Wheeler, W. Anderson, and H. Bamford.	150
Editing a new Edition of 'Anthropological Notes and Queries.'	*Chairman.*—Professor Flower. *Secretary.*—Dr. Garson. Dr. Beddoe, General Pitt-Rivers, Mr. Francis Galton, and Dr. E. B. Tylor.	50

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
For carrying on the Work of the Anthropometric Laboratory.	*Chairman.*—Professor Flower. *Secretary.*—Dr. Garson. Mr. Bloxam and Dr. Wilberforce Smith.	£ 10
The Physical Characters, Languages, and Industrial and Social Condition of the North-Western Tribes of the Dominion of Canada.	*Chairman.*—Dr. E. B. Tylor. *Secretary.*—Mr. Bloxam. Sir Daniel Wilson, Dr. G. M. Dawson, and Mr. R. G. Haliburton.	200
The Habits, Customs, Physical Characteristics, and Religions of the Natives of India.	*Chairman.*—Sir William Turner. *Secretary.*—Mr. Bloxam. Professor Flower, Drs. Garson and E. B. Tylor, and Mr. H. H. Risley.	10
Corresponding Societies Committee.	*Chairman.*—Mr. Francis Galton. *Secretary.*—Professor R. Meldola. Professor A. W. Williamson, Sir Douglas Galton, Professor Boyd Dawkins, Sir Rawson Rawson, Dr. J. G. Garson, Dr. John Evans, Mr. J. Hopkinson, Mr. W. Whitaker, Mr. G. J. Symons, General Pitt-Rivers, Mr. W. Topley, and Professor Bonney.	25

2. *Not receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee
The Collection and Identification of Meteoric Dust.	*Chairman.*—Mr. John Murray. *Secretary.*—Mr. John Murray. Professor Schuster, Sir William Thomson, the Abbé Renard, Mr. A. Buchan, the Hon. R. Abercromby, and Dr. M. Grabham.
The Rate of Increase of Underground Temperature downwards in various Localities of dry Land and under Water.	*Chairman.*—Professor Everett. *Secretary.*—Professor Everett. Professor Sir William Thomson, Mr. G. J. Symons, Sir A. C. Ramsay, Dr. A. Geikie, Mr. J. Glaisher, Mr. Pengelly, Professor Edward Hull, Professor Prestwich, Dr. C. Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, Mr. A. Strahan, and Professor Michie Smith.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
Comparing and Reducing Magnetic Observations.	*Chairman.*—Professor W. G. Adams. *Secretary.*—Professor W. G. Adams. Sir W. Thomson, Professors G. H. Darwin and G. Chrystal, Mr. C. H. Carpmael, Professor Schuster, Mr. G. M. Whipple, Captain Creak, the Astronomer Royal, Mr. William Ellis, Mr. W. Lant Carpenter, and Professor A. W. Rücker.
Considering the best Methods of Recording the Direct Intensity of Solar Radiation.	*Chairman.*—Sir G. G. Stokes. *Secretary.*—Mr. G. J. Symons. Professor Schuster, Mr. G. Johnstone Stoney, Sir H. E. Roscoe, Captain Abney, Mr. Whipple, and Professor M'Leod.
To coöperate with Dr. Kerr in his researches on Electro-optics.	*Chairman.*—Dr. John Kerr. *Secretary.*—Mr. R. T. Glazebrook. Sir W. Thomson and Professor Rücker.
For Calculating Tables of certain Mathematical Functions, and, if necessary, for taking steps to carry out the Calculations, and to publish the results in an accessible form.	*Chairman.*—Lord Rayleigh. *Secretary.*—Professor A. Lodge. Sir William Thomson, Professor Cayley, Professor B. Price, and Messrs. J. W. L. Glaisher, A. G. Greenhill, and W. M. Hicks.
Carrying on the Tables connected with the Pellian Equation from the point where the work was left by Degen in 1817.	*Chairman.*—Professor Cayley. *Secretary.*—Professor A. Lodge. Professor Sylvester and Mr. A. R. Forsyth.
The various Phenomena connected with the recalescent Points in Iron and other Metals.	*Chairman.*—Professor Fitzgerald. *Secretary.*—Professor Barrett. Dr. John Hopkinson, Mr. R. A. Hadfield, Mr. Trouton, Professor Roberts-Austen, and Mr. H. F. Newall.
Reporting on the Bibliography of Solution.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Dr. W. W. J. Nicol. Professors M'Leod, Pickering, Ramsay, and Young and Dr. A. R. Leeds.
To report on recent Inquiries into the History of Chemistry.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Professor John Ferguson.
The Continuation of the Bibliography of Spectroscopy.	*Chairman.*—Professor H. M'Leod. *Secretary.*—Professor Roberts-Austen. Professor Reinold and Mr. H. G. Madan.
Preparing a new Series of Wave-length Tables of the Spectra of the Elements.	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—Dr. Marshall Watts. Mr. Lockyer, Professors Dewar, Liveing, Schuster, W. N. Hartley, and Wolcott Gibbs, and Captain Abney.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
The Properties of Solutions . . .	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Dr. W. W. J. Nicol. Professor Ramsay.
The Influence of the Silent Discharge of Electricity on Oxygen and other Gases.	*Chairman.*—Professor H. M'Leod. *Secretary.*—Mr. W. A. Shenstone. Professor Ramsay and Mr. J. T. Cundall.
The Action of Light on the Hydracids of the Halogens in presence of Oxygen.	*Chairman.*—Dr. Russell. *Secretary.*—Dr. A. Richardson. Captain Abney and Professors Noel Hartley and W. Ramsay.
Absorption Spectra of Pure Compounds.	*Chairman.*—General Festing. *Secretary.*—Dr. H. E. Armstrong. Captain Abney.
The Rate of Erosion of the Sea-coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other material in that action.	*Chairman.*—Mr. R. B. Grantham. *Secretaries.*—Messrs. C. E. De Rance and W. Topley. Messrs. J. B. Redman, W. Whitaker, and J. W. Woodall, Maj.-Gen. Sir A. Clarke, Admiral Sir E. Ommanney, Sir J. N. Douglass, Capt. Sir G. Nares, Capt. J. Parsons, Capt. W. J. L. Wharton, Professor J. Prestwich, and Messrs. E. Easton, J. S. Valentine, and L. F. Vernon Harcourt.
To carry on Excavations at Oldbury Hill, near Ightham, in order to ascertain the existence or otherwise of Rock Shelters at that spot.	*Chairman.*—Dr. J. Evans. *Secretary.*—Mr. B. Harrison. Professors Prestwich and H. G. Seeley.
Considering the advisability and possibility of establishing in other parts of the country Observations upon the Prevalence of Earth Tremors similar to those now being made in Durham in connection with coal-mine explosions.	*Chairman.*—Mr. G. J. Symons. *Secretary.*—Mr. C. Davison. Sir F. J. Bramwell, Mr. E. A. Cowper, Professor G. H. Darwin, Professor Ewing, Mr. Isaac Roberts, Mr. Thomas Gray, Dr. John Evans, Professors Prestwich, Hull, Lebour, Meldola, and Judd, Mr. M. Walton Brown, and Mr. J. Glaisher.
To undertake the Investigation of the Sources of the River Aire, and also to test the value of Uranin and other Dyes in investigating the Courses of Underground Streams.	*Chairman.*—Professor R. Meldola. *Secretary.*—Professor Silvanus P. Thompson. Mr. J. Birbeck, Mr. Walter Morrison, M.P., Rev. Dr. Styles, and Mr. Thomas Tate.
The Invertebrate Fauna and Cryptogamic Flora of the Fresh Waters of the British Isles.	*Chairman.*—Professor Bayley Balfour. *Secretary.*—Professor J. C. Ewart. Canon A. M. Norman, Professors J. Geikie, A. C. Haddon, T. Johnston, W. J. Sollas, and Lapworth, Dr. H. Scott, and Mr. F. E. Beddard.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
To make a Digest of the Observations on the Migration of Birds at Lighthouses and Light-vessels, which have been carried on by the Migration Committee of the British Association.	*Chairman.*—Professor Newton. *Secretary.*—Mr. John Cordeaux. Messrs. John A. Harvie-Brown, R. M. Barrington, and W. E. Clarke and the Rev. E. P. Knubley.
The Teaching of Science in Elementary Schools.	*Chairman.*—Dr. J. H. Gladstone. *Secretary.*—Professor H. E. Armstrong. Mr. S. Bourne, Dr. Crosskey, Mr. George Gladstone, Mr. J. Heywood, Sir J. Lubbock, Sir Philip Magnus, Professor N. Story Maskelyne, Sir H. E. Roscoe, Sir R. Temple, and Professor Silvanus P. Thompson.
Ascertaining and recording the Localities in the British Islands in which evidences of the existence of Prehistoric Inhabitants of the country are found.	*Chairman.*—Sir John Lubbock. *Secretary.*—Mr. J. W. Davis. Dr. J. Evans, Professor Boyd Dawkins, Dr. R. Munro, Messrs. Pengelly and Hicks, Professor Meldola, and Dr. Muirhead.

Other Resolutions adopted by the General Committee.

That Mr. W. N. Shaw be requested to continue his Report on the present state of our Knowledge in Electrolysis and Electro-chemistry.

That in the event of the President of a Section being unable to attend a meeting of the Committee of Recommendations, the Sectional Committee shall be authorised to appoint a Vice-President, or, failing a Vice-President, some other member of the Committee, to attend in his place; due notice of the appointment being sent to the Assistant General Secretary.

That Professor H. S. Hele Shaw, who has hitherto served as Secretary of the Committee appointed to report on the Development of Graphic Methods in Mechanical Science, be appointed to complete the Report and present it at next year's meeting of the Association.

Communications ordered to be printed in extenso *in the Annual Report of the Association.*

(1) Reports of the discussion on Electrolysis and of the discussion on Solution prepared by Dr. Thorpe.

(2) The paper by Professor J. E. C. Munro, LL.D., entitled 'The probable Effects on Wages of a general Reduction in the Hours of Labour.'

(3) The paper by Professors Barr and Stroud on 'New Telemeters and Range Finders,' with the necessary drawings.

Resolutions referred to the Council for consideration, and action if desirable.

That the Council consider and report whether grants should be made from the funds of the Association for other than specific researches by specified individuals.

That the Council be requested to consider the question of watching the operation of Acts relating to Scientific and Technical Education, and to take such steps as may seem desirable for furthering the objects of those Acts.

That the Council be requested to consider whether it is not desirable to make special provision for the comprehensive consideration by the Association of questions relating to Scientific and Technical Education.

That the Council urge upon Government to take steps to hasten the completion of the Ordnance Survey and to afford the public greater facilities for the purchase of the Survey Maps.

That it is desirable that the question of publishing the papers more fully and expeditiously and of adding reports of discussions be considered by the Council.

That in the arrangement of the Journal it is desirable, in the interests of clearness and of ease of reference, to return to the old practice of printing first the papers to be read in the various sections, then the papers read on the previous day in those sections, and lastly, the list of sectional officers and of the committees.

That the Council be requested, if possible, to fix the date of each Meeting two years before it is held, and to bear in mind that the middle or latter part of September is the time most convenient to many Members of the Association.

That a General Index to the Reports of the Committees of the Association and of all papers ordered to be printed *in extenso* be published, and that the Council be authorised to expend such sums as may be necessary for the purpose.

That the hours at which the Sections and Committees meet be again considered by the Council.

That the paper by Mr. J. F. Green, on 'Steam Life Boats,' be printed *in extenso* with the necessary drawings.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Leeds Meeting, in September 1890. The Names of the Members entitled to call on the General Treasurer for the respective Grants are prefixed.

Mathematics and Physics.

	£	s.	d.
*Thomson, Sir W.—Seismological Phenomena of Japan	10	0	0
*Foster, Professor Carey.—Electrical Standards	100	0	0
*McLaren, Lord.—Meteorological Observations on Ben Nevis	50	0	0
*Fitzgerald, Professor.—Electrolysis	5	0	0
Symons, Mr. G. J.—Photographs of Meteorological Phenomena	5	0	0
Lodge, Professor O. J.—Discharge of Electricity from Points	10	0	0
Liveing, Professor.—Ultra Violet Rays of Solar Spectrum ...	50	0	0
*Murray, Mr. John.—Seasonal Variations of Temperature ...	20	0	0

Chemistry.

*Roberts-Austen, Professor.—Analysis of Iron and Steel......	10	0	0
*Tilden, Professor.—Isomeric Naphthalene Derivatives	25	0	0
Armstrong, Professor H. E.—Formation of Haloid Salts......	25	0	0
Thorpe, Dr.—Action of Light upon Dyes	20	0	0

Geology.

*Prestwich, Professor.—Erratic Blocks	10	0	0
*Etheridge, Mr. R.—Fossil Phyllopoda	10	0	0
*Whitaker, Mr. W.—Geological Record	100	0	0
*Geikie, Professor J.—Photographs of Geological Interest ...	10	0	0
*Woodward, Dr. H.—Lias Beds in Northamptonshire	25	0	0
*Woodward, Dr. H.—Registration of Type Specimens of British Fossils	10	0	0
*Bauerman, Mr. H.—Volcanic Phenomena of Vesuvius	10	0	0
*Hull, Professor E.—Underground Waters........................	5	0	0
*Davis, Mr. J. W.—Investigation of Elbolton Cave	25	0	0

Biology.

*Flower, Professor W. H.—Marine Biological Association at Plymouth...	30	0	0
*Foster, Professor Michael.—Botanical Station at Peradeniya	50	0	0
Carried forward..	£615	0	0

* Reappointed.

	£	s.	d.
Brought forward	615	0	0
*Haddon, Professor A. C.—Improving Deep-sea Tow-net	40	0	0
*Wills, Mr. A. W.—Disappearance of Native Plants	5	0	0
Flower, Professor W. H.—Zoology of the Sandwich Islands	100	0	0
*Flower, Professor W. H.—Zoology and Botany of the West India Islands	100	0	0
Geography.			
*Garson, Dr.—Nomad Tribes of Asia Minor and Northern Persia	30	0	0
Mechanical Science.			
*Douglass, Sir J.—Action of Waves and Currents in Estuaries	150	0	0
Anthropology.			
*Flower, Professor.—New Edition of 'Anthropological Notes and Queries'	50	0	0
*Flower, Professor.—Anthropometric Laboratory	10	0	0
*Tylor, Dr. E. B.—North-Western Tribes of Canada	200	0	0
*Turner, Sir W.—Habits of Natives of India	10	0	0
*Symons, Mr. G. J.—Corresponding Societies	25	0	0
	£1,335	0	0

* Reappointed.

The Annual Meeting in 1891.

The Meeting at Cardiff will commence on Wednesday, August 19.

Place of Meeting in 1892.

The Annual Meeting of the Association will be held at Edinburgh.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-Iron Experiments	103	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	171	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	166	16	6
Animal Secretions	10	10	0
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0

	£	s.	d.
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology......1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	5	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

	£	s.	d.
1848.			
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8
1849.			
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6
1850.			
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

	£	s.	d.
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855.			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4
1856.			
Maintaining the Establishment at Kew Observatory:— 1854......£ 75 0 0; 1855......£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	0
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0

	£	s.	d.
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahagow	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connection of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0

	£	s.	d.
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance......	150	0	0
Thermo-Electric Currents ...	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory...	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal...........	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards............	100	0	0
Electrical Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida..........................	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory..	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland ...	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee ...	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays.....................	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment of Kew Observatory..	600	0	0
Balloon Committee	100	0	0
Hydroida..........................	13	0	0
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation ...	10	0	0
Eurypterus	50	0	0
Electrical Standards............	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches...	150	0	0
Kent's Hole Excavations......	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands ...	50	0	0
Zoological Nomenclature......	5	0	0
Resistance of Floating Bodies in Water.......................	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment of Kew Observatory..	600	0	0
Lunar Committee...............	64	13	4
Balloon Committee	50	0	0
Metrical Committee...........	50	0	0
British Rainfall.................	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed ...	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation ...	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards............	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast ...	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water.......................	50	0	0
Polycyanides of Organic Radicals	29	0	0

	£	s.	d.
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-Beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyl and Methyl series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0

	£	s.	d.
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat.............................	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee............	25	0	0
Zoological Record..............	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood..............	7	2	6
British Rainfall..................	50	0	0
Kent's Hole Explorations ...	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-Beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	300	0	0
Metrical Committee............	75	0	0
Zoological Record..............	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab...........	100	0	0
Terato-Embryological Inquiries	10	0	0
Kent's Cavern Exploration..	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood..............	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta ...	25	0	0
Lunar Objects	20	0	0
Inverse Wave-Lengths.........	20	0	0
British Rainfall..................	100	0	0
Poisonous Substances Antagonism............................	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record..............	100	0	0
Chemistry Record...............	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration ...	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-Lengths	150	0	0
British Rainfall..................	100	0	0
Essential Oils.....................	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations...	25	0	0
Underground Temperature ...	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland...........	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors..............	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record..............	100	0	0
Chemistry Record..............	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions..............	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions, &c.	50	0	0
Kent's Cavern Exploration ...	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall..................	100	0	0
Essential Oils.....................	10	0	0
Sub-Wealden Explorations ...	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorological Research	100	0	0
Magnetisation of Iron	20	0	0
Marine Organisms..............	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-Corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-Measures..........................	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetisation of Iron	20	0	0
British Rainfall..................	120	0	0
Luminous Meteors	3[illegible]	0	0
Chemistry Record..............	100	0	0

	£	s.	d.
Specific Volume of Liquids...	25	0	0
Estimation of Potash and Phosphoric Acid..............	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations ...	100	0	0
Kent's Cavern Exploration...	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record..............	100	0	0
Instructions for Travellers ...	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall.................	100	0	0
Ohm's Law.......................	9	15	0
Tide Calculating Machine ...	200	0	0
Specific Volume of Liquids...	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodacetoacetate.........................	5	0	0
Estimation of Potash and Phosphoric Acid..............	13	0	0
Exploration of Victoria Cave, Settle	100	0	0
Geological Record..............	100	0	0
Kent's Cavern Exploration...	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland......	1	10	0
Zoological Record..............	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Zoological Station..............	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles......	13	15	0
Measuring Speed of Ships ...	10	0	0
Effect of Propeller on turning of Steam Vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acids in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record..............	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpæ, Report on......	20	0	0
Mechanical Equivalent of Heat............................	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperatures	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodacetoacetate	10	0	0
British Earthworks	25	0	0
Atmospheric Elasticity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid..............	1	18	0
Geological Record..............	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c...............	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record..............	100	0	0
Investigation of Pulse Phenomena by means of Syphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters..........................	15	0	0
Transmission of Electrical Impulses through Nerve Structure.......................	30	0	0
Calculation of Factor Table of Fourth Million	100	0	0
Anthropometric Committee...	66	0	0
Chemical Composition and Structure of less known Alkaloids...........	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors..............	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland ...	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0

	£	s.	d.
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Circulation of Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature	20	0	0
Electrical Standards	25	0	0
High Insulation Key	5	0	0
Tidal Observations	10	0	0
Specific Refractions	7	3	1
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station	50	0	0
Naples Zoological Station	75	0	0
Natural History of Socotra	50	0	0
Anthropological Notes and Queries	9	0	0
Zoological Record	100	0	0
Weights and Heights of Human Beings	30	0	0
	£476	3	1

1882.

	£	s.	d.
Exploration of Central Africa	100	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Standards for Electrical Measurements	100	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements	50	0	0
Photographing Ultra-Violet Spark Spectra	25	0	0
Geological Record	100	0	0
Earthquake Phenomena of Japan	25	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Fossil Plants of Halifax	15	0	0
Geological Map of Europe	25	0	0
Circulation of Underground Waters	15	0	0

	£	s.	d.
Tertiary Flora of North of Ireland	20	0	0
British Polyzoa	10	0	0
Exploration of Caves of South of Ireland	10	0	0
Exploration of Raygill Fissure	20	0	0
Naples Zoological Station	80	0	0
Albuminoid Substances of Serum	10	0	0
Elimination of Nitrogen by Bodily Exercise	50	0	0
Migration of Birds	15	0	0
Natural History of Socotra	100	0	0
Natural History of Timor-laut	100	0	0
Record of Zoological Literature	100	0	0
Anthropometric Committee	50	0	0
	£1126	1	11

1883.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Isomeric Naphthalene Derivatives	15	0	0
Earthquake Phenomena of Japan	50	0	0
Fossil Plants of Halifax	20	0	0
British Fossil Polyzoa	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Circulation of Underground Waters	15	0	0
Geological Record	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Zoological Literature Record	100	0	0
Migration of Birds	20	0	0
Zoological Station at Naples	80	0	0
Scottish Zoological Station	25	0	0
Elimination of Nitrogen by Bodily Exercise	38	3	3
Exploration of Mount Kilima-njaro	500	0	0
Investigation of Loughton Camp	10	0	0
Natural History of Timor-laut	50	0	0
Screw Gauges	5	0	0
	£1083	3	3

1884.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Collecting and Investigating Meteoric Dust	20	0	0
Meteorological Observatory at Chepstow	25	0	0
Tidal Observations	10	0	0
Ultra-Violet Spark Spectra	8	4	0
Earthquake Phenomena of Japan	75	0	0
Fossil Plants of Halifax	15	0	0
Fossil Polyzoa	10	0	0
Erratic Blocks of England	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Circulation of Underground Waters	5	0	0
International Geological Map	20	0	0
Bibliography of Groups of Invertebrata	50	0	0
Natural History of Timor-laut	50	0	0
Naples Zoological Station	80	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Migration of Birds	20	0	0
Coagulation of Blood	100	0	0
Zoological Literature Record	100	0	0
Anthropometric Committee	10	0	0
	£1173	4	0

1885.

	£	s.	d.
Synoptic Chart of Indian Ocean	50	0	0
Reduction of Tidal Observations	10	0	0
Calculating Tables in Theory of Numbers	100	0	0
Meteorological Observations on Ben Nevis	50	0	0
Meteoric Dust	70	0	0
Vapour Pressures, &c., of Salt Solutions	25	0	0
Physical Constants of Solutions	20	0	0
Volcanic Phenomena of Vesuvius	25	0	0
Raygill Fissure	15	0	0
Earthquake Phenomena of Japan	70	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Fossil Plants of British Tertiary and Secondary Beds	50	0	0
Geological Record	50	0	0
Circulation of Underground Waters	10	0	0
Naples Zoological Station	100	0	0
Zoological Literature Record	100	0	0
Migration of Birds	30	0	0
Exploration of Mount Kilima-njaro	25	0	0
Recent Polyzoa	10	0	0
Marine Biological Station at Granton	100	0	0
Biological Stations on Coasts of United Kingdom	150	0	0
Exploration of New Guinea	200	0	0
Exploration of Mount Roraima	100	0	0
	£1385	0	0

1886.

	£	s.	d.
Electrical Standards	40	0	0
Solar Radiation	9	10	6
Tidal Observations	50	0	0
Magnetic Observations	10	10	0
Meteorological Observations on Ben Nevis	100	0	0
Physical and Chemical Bearings of Electrolysis	20	0	0
Chemical Nomenclature	5	0	0
Fossil Plants of British Tertiary and Secondary Beds	20	0	0
Exploration of Caves in North Wales	25	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Geological Record	100	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Zoological Literature Record	100	0	0
Marine Biological Station at Granton	75	0	0
Naples Zoological Station	50	0	0
Researches in Food-Fishes and Invertebrata at St. Andrews	75	0	0
Migration of Birds	30	0	0
Secretion of Urine	10	0	0
Exploration of New Guinea	150	0	0
Regulation of Wages under Sliding Scales	10	0	0
Prehistoric Race in Greek Islands	20	0	0
North-Western Tribes of Canada	50	0	0
	£995	0	6

1887.

	£	s.	d.
Solar Radiation	18	10	0
Electrolysis	30	0	0
Ben Nevis Observatory	75	0	0
Standards of Light (1886 grant)	20	0	0
Standards of Light (1887 grant)	10	0	0
Harmonic Analysis of Tidal Observations	15	0	0
Magnetic Observations	26	2	0
Electrical Standards	50	0	0
Silent Discharge of Electricity	20	0	0
Absorption Spectra	40	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Volcanic Phenomena of Japan (1887 grant)	50	0	0
Exploration of Cae Gwyn Cave, North Wales	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	20	0	0
Coal Plants of Halifax	25	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Exploration of the Eocene Beds of the Isle of Wight	20	0	0
Circulation of Underground Waters	5	0	0
'Manure' Gravels of Wexford	10	0	0
Provincial Museum Reports	5	0	0
Investigation of Lymphatic System	25	0	0
Naples Biological Station	100	0	0
Plymouth Biological Station	50	0	0
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Flora and Fauna of the Cameroons	75	0	0
Migration of Birds	30	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Regulation of Wages	10	0	0
Prehistoric Race of Greek Islands	20	0	0
Racial Photographs, Egyptian	20	0	0
	£1186	18	0

1888.

	£	s.	d.
Ben Nevis Observatory	150	0	0
Electrical Standards	2	6	4
Magnetic Observations	15	0	0
Standards of Light	79	2	3
Electrolysis	30	0	0
Uniform Nomenclature in Mechanics	10	0	0
Silent Discharge of Electricity	9	11	10
Properties of Solutions	25	0	0
Influence of Silicon on Steel	20	0	0
Methods of Teaching Chemistry	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Action of Light on Hydracids	20	0	0
Sea Beach near Bridlington	20	0	0
Geological Record	50	0	0
Manure Gravels of Wexford	10	0	0
Erosion of Sea Coasts	10	0	0
Circulation of Underground Waters	5	0	0
Palæontographical Society	50	0	0
Pliocene Fauna of St. Erth	50	0	0
Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Zoology and Botany of West Indies	100	0	0
Flora of Bahamas	100	0	0
Development of Fishes—St. Andrews	50	0	0
Marine Laboratory, Plymouth	100	0	0
Migration of Birds	30	0	0
Flora of China	75	0	0

	£	s.	d.
Naples Zoological Station ...	100	0	0
Lymphatic System	25	0	0
Biological Station at Granton	50	0	0
Peradeniya Botanical Station	50	0	0
Development of Teleostei ...	15	0	0
Depth of Frozen Soil in Polar Regions	5	0	0
Precious Metals in Circulation	20	0	0
Value of Monetary Standard	10	0	0
Effect of Occupations on Physical Development............	25	0	0
North-Western Tribes of Canada	100	0	0
Prehistoric Race in Greek Islands.........................	20	0	0
	£1511	0	5

1889.

	£	s.	d.
Ben Nevis Observatory.........	50	0	0
Electrical Standards............	75	0	0
Electrolysis........................	20	0	0
Observations on Surface Water Temperature	30	0	0
Silent Discharge of Electricity on Oxygen	6	4	8
Methods of teaching Chemistry	10	0	0
Action of Light on Hydracids	10	0	0
Geological Record..............	80	0	0
Volcanic Phenomena of Japan	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Fossil Phyllopoda of Palæozoic Rocks	20	0	0
Higher Eocene Beds of Isle of Wight	15	0	0
West Indian Explorations ...	100	0	0
Flora of China	25	0	0
Naples Zoological Station ...	100	0	0
Physiology of Lymphatic System	25	0	0
Experiments with a Tow-net	5	16	3
Natural History of Friendly Islands..........................	100	0	0
Geology and Geography of Atlas Range...	100	0	0
Action of Waves and Currents in Estuaries by means of Working Models	100	0	0
North-Western Tribes of Canada	150	0	0
Characteristics of Nomad Tribes of Asia Minor.........	30	0	0
Corresponding Societies	20	0	0
Marine Biological Association	200	0	0
Bath 'Baths Committee' for further Researches	100	0	0
	£1417	0	11

1890.

	£	s.	d.
Electrical Standards............	12	17	0
Electrolysis	5	0	0
Electro-optics.....................	50	0	0
Calculating Mathematical Tables	25	0	0
Volcanic and Seismological Phenomena of Japan	75	0	0
Pellian Equation Tables	15	0	0
Properties of Solutions	10	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Influence of the Silent Discharge of Electricity on Oxygen	5	0	0
Methods of teaching Chemistry	10	0	0
Recording Results of Water Analysis	4	1	0
Oxidation of Hydracids in Sunlight	15	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Fossil Phyllopoda of the Palæozoic Rocks.................	10	0	0
Circulation of Underground Waters.........................	5	0	0
Excavations at Oldbury Hill	15	0	0
Cretaceous Polyzoa	10	0	0
Geological Photographs	7	14	11
Lias Beds of Northamptonshire	25	0	0
Botanical Station at Peradeniya	25	0	0
Experiments with a Tow-net	4	3	9
Naples Zoological Station ...	100	0	0
Zoology and Botany of the West India Islands	100	0	0
Marine Biological Association	30	0	0
Action of Waves and Currents in Estuaries	150	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Calculations	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Corresponding Societies	20	0	0
	£799	16	8

General Meetings.

On Wednesday, September 3, at 8 P.M., in the Coliseum, Professor W. H. Flower, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., resigned the office of President to Sir Frederick Abel, C.B., D.C.L., D.Sc., F.R.S., V.P.C.S., who took the Chair, and delivered an Address, for which see page 1.

On Thursday, September 4, at 8 P.M., a Soirée took place in the Municipal Buildings.

On Friday, September 5, at 8.30 P.M., in the Coliseum, E. B. Poulton, Esq., M.A., F.R.S., F.G.S., delivered a discourse on 'Mimicry.'

On Monday, September 8, at 8.30 P.M., in the Coliseum, Professor C. Vernon Boys, F.R.S., delivered a discourse on 'Quartz Fibres and their Applications.'

On Tuesday, September 9, at 8 P.M., a Soirée took place in the Municipal Buildings.

On Wednesday, September 10, at 2.30 P.M., in the Philosophical Hall, the concluding General Meeting took place, when the Proceedings of the General Committee and the Grants of Money for Scientific Purposes were explained to the Members.

The Meeting was then adjourned to Cardiff. [The Meeting is appointed to commence on Wednesday, August 19, 1891.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

SIR FREDERICK AUGUSTUS ABEL,

C.B., D.C.L. (Oxon.), D.Sc. (Cant.), F.R.S., P.P.C.S., Hon.M.Inst.C.E.,

PRESIDENT.

Many who had the pleasure of listening last year, at Newcastle, to the interesting and instructive Address of the President to whom I am a most unworthy successor, could not fail, both by the chief subject of his discourse and by the circumstance of the official position which he occupies with so much benefit to science and the public, to have their thoughts directed to the illustrious naturalist whose philosophical Address delighted the members of the Association and the people of Leeds thirty-two years ago.

More than one-half the period of existence of this Association has passed since Richard Owen presided over its meeting in this town. Alas! what gaps have been created in the ranks of those who at that time were prominent for activity in advancing its work: the then General Secretary, Sir Edward Sabine; the all-popular Assistant-general Secretary, John Phillips; the Treasurer, John Taylor, now live with us only through their works and the enduring esteem which they inspired. But very few of those who held other prominent positions at that meeting have survived to see the Association reassemble in this town. Whewell, Herschel, Hopkins, the elder Brodie, Murchison, William Fairbairn, all Presidents of Sections in 1858, have long since been removed from among us; and the then President of Section F, Edward Baines, a much-honoured and highly-talented son of the 'Franklin of Leeds,' whom we had hoped to count among those Vice-Presidents representing the city on this occasion, has recently passed away, in his ninetieth year, after a most honourable and useful career, during which he especially distinguished himself by his successful exertions in the advancement of the great educational movements of his time.

The illustrious President of our last meeting here, concerning whose health the gravest apprehensions were not long since entertained, is happily still preserved to us; still intellectually bright at the ripe age of eighty-six, and still, with the keen pleasure of his early life, following the progress of those branches of scientific research which have constituted the favourite occupations and the arena of many intellectual triumphs of a long career of ardent and successful devotion to the advancement of science.

To not a few of those who have flocked to Leeds to attend the annual gathering of this Association, our present meeting-place is doubtless known chiefly by its proud position as one of the most thriving manufacturing towns of the United Kingdom; of ancient renown, especially in connection with one of the chief industries identified with Great Britain in years past. But this good town of Leeds, whose cloth market was described by Daniel Defoe, one hundred and sixty odd years ago, as 'a prodigy of its kind, and not to be equalled in the world,' and whose present position in connection with divers of our great industries would have equally excited the enthusiasm of that graphic writer, is famous for other things than its prominent association with manufactures and commerce.

Not many of our great industrial centres can boast of so goodly an array, upon the scroll of their past history, of names of men eminent in the Sciences, the Arts and Manufactures, in Divinity and Letters, and in heroic achievements, such as are identified with Leeds and its immediate vicinity: Thomas, Lord Fairfax, one of the most prominent heroes of the Commonwealth; Smeaton, an intellectual giant among engineers; William Hirst and John Marshall, illustrious examples of the men who by their genius, energy, and perseverance placed Great Britain upon the pinnacle of industrial and commercial greatness which she so long occupied unassailed; Richard Bentley, the eminent classic and divine; John Nicholson, the Airedale poet; John Fowler and Peter Fairbairn, worthy followers in the footsteps of Smeaton; Isaac Milner, weaver and mathematician, afterwards Senior Wrangler, Smith's prizeman, Jacksonian Professor, President of Queens' College, Vice-Chancellor of Cambridge University, Dean of Carlisle, and a most illustrious Fellow of the Royal Society; Thoresby, antiquarian and topographer; Benjamin Wilson, painter, and industrious contributor to the development of electrical science; William Hey, the eminent surgeon, and friend and counsellor of Priestley; Sadler, political economist and philanthropist; the brothers Sheepshanks—Richard, the astronomer, and John, the accomplished patron of the arts, and munificent contributor to our national art treasures; Edward Baines, whose conspicuous talents and energy developed a small provincial journal into one of the most powerful public organs of the country; his talented sons, of whom not the least conspicuous and highly respected was the late Sir Edward Baines. I might swell this voluminous list by reference to illustrious members of such families as those of Denison, of Beckett, of Lowther, but the men I have referred to fitly illustrate the remarkable array of worthies whose careers have shed lustre upon the town in or near which they were born. Yet that illustration would be altogether incomplete if I failed to speak of one whose career and works alone would suffice to place Leeds in the foremost rank of those English towns which can claim as their own men whose course of life and whose achievements have secured their pre-eminence among our illustrious countrymen. Needless to say that I refer to Joseph Priestley, born within six miles of Leeds, whose name holds rank among the foremost of successful workers in science; who, by brilliant powers of experimental investigation, rapidly achieved a series of discoveries which helped largely to dispel the shroud of mystery surrounding the art of alchemy, and to lay the foundation of true chemical science. An ardent student of the classics, of Eastern languages, and of divinity, a zealous exponent of theological doctrines which marred his career as divine and instructor, he early displayed conspicuous talents for the cultivation of experimental science, which he pursued with ardour under formidable difficulties. His acquaintance with Franklin probably developed the taste for the study of electric science which led him to labour successfully in this direction; and the publication, in 1767, of his valuable work on 'The History and Present State of Electricity, with Original Experiments,' secured for him a prominent position among the working Fellows of the Royal Society. His connection with Mill Hill Chapel, in 1768, appears to have given rise accidentally to his first embracing the experimental pursuit of what formerly was termed pneumatic chemistry, the foundation of which had been laid by Cavendish's memorable contribution, in 1766, to the 'Philosophical Transactions,' on carbonic acid and hydrogen. Priestley's first publication in pneumatic chemistry, on 'Impregnating Water with Fixed Air' (carbonic acid), attracted great attention; it was at once translated into French, and the College of Physicians addressed the Lords of the Treasury thereon, pointing out the advantages which might result from the employment, by men at sea, of water impregnated with carbonic acid gas, as a protective against, or cure for, scurvy.

Six years later Priestley investigated the chemical effects produced on the air by the burning of candles and the respiration of animals, and, having demonstrated that it was thereby diminished in volume and deteriorated, he showed that living plants possessed the power of rendering air, which had been thus deteriorated, once more capable of supporting the combustion of a candle. At about this time Priestley received very advantageous proposals to accompany Captain Cook upon his second expedition to the South Seas; but when about to prepare for his departure he learned from Sir Joseph Banks that objections against his appointment, on account of the great latitude of his religious principles, had been successfully urged by some ecclesiastic member of the Board of Longitude. In 1773 the Royal Society awarded

Priestley the Copley Medal for a remarkable paper entitled 'Observations on Different Kinds of Air,' and in that year he became librarian and literary companion to the Earl of Shelbourne (afterwards Marquis of Lansdowne), and thereby secured special advantages in the pursuit of his scientific researches.

With respect to his departure from Leeds, he expressed himself as having been very happy there 'with a liberal, friendly, and harmonious congregation, to whom my services (of which I was not sparing) were very acceptable. Here I had no unreasonable prejudices to contend with, so that I had full scope for every kind of exertion; and I can truly say that I always considered the office of a Christian minister as the most honourable of any upon earth, and in the studies proper to it I always took the greatest pleasure.' During the next five years he published as many volumes describing the results of important experiments on air. After investigating the properties of nitric oxide, and applying it to the analysis of air, Priestley, in 1774, discovered and carefully studied oxygen, which he obtained by the action of heat upon the red oxide of mercury. He was the first to prepare and study sulphurous acid, carbonic oxide, nitrous oxide, hydrochloric acid (*marine acid air*), and the fluoride of silicon, and carried out important researches on the properties of hydrogen, and of other gases previously but little known. His great quickness of perception and power of experiment led him to the achievement of many novel and important results. But one cannot help contrasting his somewhat random search after new discoveries with the close logical reasoning and philosophic spirit which guided and pervaded the remarkable researches of him whose departure from amongst us since the last gathering of this Association is so universally deplored—of the great discoverer of the universal law of the conservation of energy, James Prescott Joule. I could not add to the judicious and graceful reference to his work which Sir Henry Roscoe was privileged to make, in the last year of that philosopher's valuable life, when presiding over the recent meeting of the Association in the town which gloried in numbering Joule among its citizens; but I may, perhaps, be permitted to express the sanguine hope that the desire of the scientific world to secure the establishment of an international memorial fitly commemorative of his great life-work may be realised in the most ample manner.

The wide scope of the admirable discourse delivered by Owen in this town thirty-two years ago affords an interesting illustration of the delight which men whose best energies are devoted to the cultivation of one particular branch of science take in the results of the labours of their fellow-workers in other departments, and in their achievements in contributing to the general advancement of our knowledge of Nature's laws and of their operations. It is to this bond of intimate union between all workers in pure science that we owe the instructive reviews of the progress made in different departments of science, with which we have often been presented at our annual gatherings. On the other hand, those men, from time to time selected to fill the distinguished office of President, whose lives have been mainly devoted to the practical utilisation of the results of scientific research, and to the extension in particular directions of the consequent resources of civilisation, seize with keen pleasure the opportunity afforded them of directing attention to the triumphs achieved in the application, to the purposes of daily life, of the great scientific truths established by such illustrious labourers in the fields of pure science as Newton, Dalton, Faraday, and Joule. The wide and constantly-extending domain of applied science presents, even to the superficial observer, a continually varied scene; not a year passes but some great prize falls to the lot of one or other of its explorers, and some apparently insignificant vein of treasure, struck upon but a few years back, is rapidly opened out by cunning explorers, until it leads to a mine of vast wealth, from which branch out in many directions new sources of power and might.

Among the branches of science in the practical applications of which the greatest strides have been made since the Association met at Leeds in 1858 is electricity. That year witnessed the accomplishment of the first great step towards the establishment of electrical communication between Europe and America, by the laying of a telegraph-cable connecting Newfoundland with Valencia. Through this cable a message of thirty-one words was shortly afterwards transmitted in thirty-five minutes; an achievement which, though exciting great enthusiasm at the time, scarcely afforded promise of the succession of triumphs in ocean telegraphy which have since surpassed the wildest dreams of the pioneers in the realms of applied electricity.

The development of the electric telegraph constitutes a never-failing subject of the liveliest interest. The experiments made by Stephen Gray, in 1727, of transmitting electrical impulses through a wire 700 feet long; by Watson, twenty years afterwards, of transmitting frictional electricity through many thousand feet of wire, supported by a line of poles, on Shooter's Hill, in Kent; and by Franklin, who carried out a similar experiment at Philadelphia,—although they were followed by many other interesting and philosophical applications of frictional electricity to the transmission of signals—were not productive of really practical results. The work of Galvani and of Volta was more fruitful of an approach to practical telegraphy in the hands of Sömmering and of Coxe, while the researches of Oersted, of Ampère, of Sturgeon, and of Ohm, and especially the discoveries of volta-electric induction and magneto-electricity by Faraday, paved the way for the development of the electric telegraph as a practical reality by Cooke and Wheatstone in 1837. How remarkable the strides have been in the resources and powers of the telegraphist since that time is demonstrated by a few such facts as these: the first needle-instrument of Cooke and Wheatstone transmitted messages at the rate of four words per minute, requiring five wires for that purpose; six messages are now conveyed by one single wire, at ten times that speed, and news is despatched at the rate of 600 words per minute. Duplex working, which more than doubled the transmitting power of a submarine cable, was soon eclipsed by the application of Edison's quadruplex working, which has in its turn been surpassed by the multiplex system, whereby six messages may be sent independently, in either direction, on one wire. When last the British Association met in Leeds, submarine telegraphy had but just started into existence; thirty years later, the accomplished President of the Mechanical Section informed us, at our meeting at Bath, that 110,000 miles of cable had been laid by British ships, and that a fleet of nearly forty ships was occupied in various oceans in maintaining existing cables and laying new ones.

The important practical achievements by which most formidable difficulties have been surmounted, step by step, in the successive attainment of the marvellous results of our day, have exerted an influence upon the advancement, not merely of electrical science, but also of science generally and of its applications, fully equal to that which they have exercised upon the development of commerce and of the intercourse between the nations of the earth.

Thus, the laying of the earliest submarine cables, between 1851 and 1855, led Sir W. Thomson, in conference with Sir George Stokes, to work out the theory of signalling in such cables, by utilising the mathematical results arrived at by Fourier in his investigation of the propagation of heat-waves. The failure of the first Atlantic cable led to the survey of the bottom of the Atlantic, which was the forerunner of deep-sea explorations, culminating in the work of the 'Challenger' Expedition, and opening up new treasures of knowledge scarcely dreamt of when last the British Association met at Leeds. To the difficulties connected with the early attempts at submarine telegraphy, and the determination with which Thomson drove home the lessons learned, we owe the systematic investigations into the causes of the variations in resistance of copper conductors, and the consequent improvements in the metallurgy of copper, which led to the realisation of the high standard of purity of metal essential for the efficient working of telegraphic systems, and also to the extensive utilisation of electricity in the production of pure copper. The rare combination of originality in powers of research and perspicuity in mathematical reasoning, with inventive and constructive genius, for which Thomson has so long been pre-eminent, has placed at the disposal of the investigator of electric science, and of the practical electrician, instruments of measurement and record which have been of incalculable value, and which owe their origin to the theoretical conclusions arrived at by him in his researches into the conditions to be fulfilled for the attainment of practical success in the construction and employment of submarine cables. The mirror galvanometer, the quadrant electrometer, the syphon-recorder, and the divided-ring electrometer, are illustrations of the valuable outcome of Thomson's labours; the combination of the last-named instrument with sliding resistance coils has rendered possible the accurate subdivision of a potential difference into 10,000 equal parts. The general use of condensers in connection with cable signalling, due to Varley's application of them for signalling through submerged cables with induced short waves, was instrumental in establishing the fact that all electro-static phenomena are simply the result of starting an electric current of known short duration round a closed circuit. The practical application of the Wheatstone Bridge led to numerous important mathematical investigations, and induced Clerk Maxwell to devise a new mode of applying determinants to the solution of the complicated electrical problems connected with networks of conductors. The necessity for the universal recognition of an electrical unit of resistance led to the establishment, in 1860, of the Electrical Standards Committee of the British Association, whose long succession of important annual reports was instrumental in most important developments of theoretical electricity, and, indeed, served to open up the whole science of electrical measurement. Matthiessen's important investigations of the electrical behaviour of metals and their alloys, and the preparation and properties of pure iron, were the outcome of the commercial demand for a practically useful standard of electrical resistance, while Latimer Clark's practical standard of electro-motive force, the mercurous sulphate cell, became invaluable to the worker in pure electrical research. The unit of resistance established by the British Association Committee received, in 1866, most important scientific application at the hands of Joule, who, by measuring the rate of development of heat in a wire of known resistance by the passage of a known current, obtained a new value of the mechanical equivalent of heat. This value differed by about 1·3 per cent. from the most accurate results arrived at by his experiments on mechanical friction, a difference which eventually proved to be exactly the error in the British Association unit of resistance; so that the true value of the unit of resistance, or Ohm, was determined by Joule fifteen years before this result was achieved by electricians. Clerk Maxwell's remarkable electro-magnetic theory of light was put to the test, through the aid of the British Association unit of resistance, by Thomson, in determining the ratio of electro-magnetic unit to the electro-static unit of quantity. Many other most interesting illustrations might be given of the invaluable aid afforded to purely scientific research by the practical results of the development of electrical science, and of the constant co-operation between the science student and the practical worker. No one could, more fitly than the late Sir William Siemens, have maintained, as he did in his admirable Address at our meeting in Southampton in 1882 that we owe most of the rapid progress of recent times to the man of science who partly devotes his energies to the solution of practical problems, and to the practitioner who finds relaxation in the prosecution of purely scientific inquiries. Most assuredly, both these classes of the world's benefactors may with equal right lay claim to rank the name of Siemens among those whom they count most illustrious!

In that highly interesting and valuable Address, delivered little more than a year before his sudden untimely removal from among us, the numerous important subjects discussed by him included not a few which he had made peculiarly his own in the wide range embraced by his enviable power of combining scientific research with practical work. Prominent among these were the applications of electric energy to lighting and heating purposes, and to the transmission of power, to the subsequent development of which his personal labours very greatly contributed.

Siemens referred to the passing of the first Electric Lighting Bill, in the year of his Presidency, as being designed to facilitate the establishment of electric installations in towns; but the anxiety of the Government of that day to protect the interests of the public through local authorities led to the assignment of such power to these over the property of lighting companies, that the utilisation of electric lighting was actually delayed for a time by those legislative measures. There can now be no doubt, however, that this delay has really been in the interests of intending suppliers and of users of the electric light, as having afforded time for the further development of practical details, connected with generation and distribution, which was vital to the attainment of a fair measure of initial success. The subsequent important modification of legislation on the subject of electric lighting, together with the practical realisation of comparatively economical methods of distribution, the establishment of fairly equitable arrangements between the public and the lighting companies, and the apportionment, so far as the metropolis is concerned, of distinct areas of operation to different competing companies, have combined to place electric lighting in this country at length upon some approach to a really sound footing, and to give the required impetus to its extensive development. Nine companies either are now, or will very shortly be, actually at work supplying, from central stations, districts of London comprising almost the entire western and north-western portions of the metropolis. As regards other parts of England, there are already twenty-seven lighting stations actually at work in different towns, besides others in course of establishment, and many more projected. The town of Leeds has not failed to give serious attention to the subject of utilising the electric light, and, although no general scheme has yet been adopted, the electricians who now visit this town will rejoice to see many of its public buildings provided with efficient electric illumination.

While the prediction made by Siemens, eight years ago, that electric lighting must take its place with us as a public illuminant, has thus been already, in a measure, fulfilled, important progress is being continuously made by the practical electrician in developing and perfecting the arrangements for the generation of the supply, its efficient distribution from centres, and its delivery to the consumer in a form in which it can be safely and conveniently dealt with and applied at an outlay which, even now, does not preclude a considerable section of the public from enjoying the decided advantages presented by electric lighting over illumination by coal-gas. Yet our recent progress in this direction, encouraging though it has been, is insignificant as compared with the strides made in the application of electric lighting in the United States, as may be gauged by the fact that, while in America the number of arc lamps in use, in April of this year, was 235,000, and of glow-lamps about three millions, there are at present about one-tenth the number of the latter, and one hundredth the number of arc lamps, in operation in England.

In some important directions we may, however, lay claim to rank foremost in the application of the electric light; thus, our large passenger-ships and our warships are provided with efficient electrical illumination; to the active operations of our Navy the electric light has become an indispensable adjunct; and our system of coast defence, by artillery and submarine mines, is equally dependent, for its thorough efficiency, upon the applications of electricity in connection with range-finding, with the arrangement and explosion of mines, and with the important auxiliary in attack and defence, the electric light, which, while so arranged, at the operating stations, as to be protected against destruction by artillery-fire and difficult of detection by the enemy, is available at any moment for affording invaluable information and important assistance and protection.

Other valuable applications of the electric light, such as its use as a lighthouse-illuminant, for the lighting of main roads in coal-mines, where its value is being increasingly appreciated, and even for signalling purposes in mid-air, through the agency of captive balloons, are continually affording fresh demonstrations of the importance of this particular branch of applied electric science.

At the Electrical Exhibition at Vienna in 1883, where, not long before the lamented death of Siemens, I had the honour of serving as one of his colleagues in the representation of British interests, the progress which had been made in the construction of electrical measuring instruments since the French Exhibition and the Electrical Congress, two years before, was very considerable. The advance in this direction has been enormous since that time; but although the practical outcome of Thomson's and of Cardew's important work has been the provision of trustworthy electrical balances and voltmeters, while efficient instruments have also been made by other well-known practical electricians, we have still to attain results in all respects satisfactory in these indispensable adjuncts to the commercial supply and utilisation of electric energy.

In connection with this important subject the recent completion of the

Board of Trade standardising laboratory, established for the purposes of arriving at and maintaining the true values of electrical units, and of securing accuracy and uniformity in the manufacture of instruments supplied by the trade for electrical measurements, may be referred to with much satisfaction as a practical illustration of official recognition of the firm root which the domestic and industrial utilisation of electric energy has taken in this country.

The achievements of the telephone were referred to by Siemens in glowing terms eight years ago; yet the results then attained were but indications of the direction in which telephonic inter-communication was destined speedily to become one of the most indispensable of present applications of electricity to the purposes of daily life. Preece, in speaking at Bath, two years ago, of the advances made in applied electricity, showed that the impediments to telephonic communication between great distances had been entirely overcome; and now, although considerably behind America and France in the use of the telephone, we are rapidly placing ourselves upon speaking terms with our friends throughout the United Kingdom. The operations of the National Telephone Company well illustrate our progress in telephonic intercommunication: that company has now 22,743 exchange lines, besides nearly 5,000 private lines; its exchanges number 272, and its call-offices 526. The number of instruments at present under rental in England is 99,000; but, important as this figure is compared to our use of the telephone a very few years ago, it sinks into insignificance by the side of the number of instruments under rental in America, which at the beginning of the present year had reached 222,430, being an increase of 16,675 over the number in 1889. Only thirteen years have elapsed since the telephone was first exhibited as a practically workable apparatus to members of the British Association at the Plymouth Meeting, and the number of instruments now at work throughout the world may be estimated as considerably exceeding a million.

The successful transmission of the electric current, and the power of control now exercised over the character which electrically-transmitted energy is made to assume, are not alone illustrated by the efficiency of the arrangements already developed for the supply of the electric light from central stations. Siemens dwelt upon this subject at Southampton with the ardent interest of one who had made its advancement one of the objects of his energetic labours in later years, and also with a prophet's prognostications of its future importance. In speaking of the electric current as having entered the lists in competition with compressed air, the hydraulic accumulator, and the quick-running rope driven by water-power, Siemens pointed out that no further loss of power was involved in the transformation of electrical into mechanical energy than is due to friction, and to the heating of the conducting wires by the resistance they oppose, and he showed that this loss, calculated upon data arrived at by Dr. John Hopkinson and by himself, amounted at the outside to 38 per cent. of the total energy. Subsequent careful researches by the Brothers Hopkinson have demonstrated that the actual loss is now far less than it was computed at in 1885; as much as 87 per cent. of the total energy transmitted being realisable at a distance, provided there be no loss in the connecting leads used.

The Paris Electric Exhibition of 1881 already afforded interesting illustrations of the performance of a variety of work by power electrically transmitted, including a short line of railway constructed by the firm of Siemens, which was a further development of the successful result already attained in Berlin by Werner Siemens in the same direction, and was, in its turn, surpassed by the considerably longer line worked by Messrs. Siemens at the Vienna Exhibition two years later. Various short lines which have since then been established by the firm of Siemens are well known, and one of the latest public acts in the valuable life of William Siemens was to assist at the opening of the electric tramway at Portrush, in the installation of which he took an active part, and where the idea, so firmly rooted in his mind from the date of his visit to the Falls of Niagara in 1876, of utilising water-power for electrical transmission—a result first achieved on a small scale by Lord Armstrong—was more practically realised than had yet been the case. Since that time Ireland has witnessed a further application of electricity to traction purposes, and of water-power to the provision of the required energy, in the working of the Bessbrook and Newry tramway, while London at length possesses an electric railway, three miles in length, to be very shortly opened, which will connect the City with one of the southern suburbs through a tram subway, and, although including many sharp curves and steep gradients, will be capable of conveying one hundred passengers at a time, at speeds varying from thirteen to twenty-four miles per hour. During the past year a regular service of tramcars has been successfully worked, through the agency of secondary batteries, upon part of one of the large tramways of North London, with results which bid fair to lead to further extensions of this system of working in the metropolis. The application of electricity to traction purposes has, however, received far more important development in the United States; at the commencement of this year there were in operation in different States 200 electrical tramroads, chiefly worked upon the Thomson-Houston and the Sprague systems, and having a collective length of 1,641 miles, with 2,346 motor-cars travelling thereon. Further extensions are being rapidly made; thus, one company alone has 39 additional roads, of a collective length of 385 miles, under construction, to be worked through the agency of storage-batteries.

The idea cherished by Siemens, and enlarged upon by him in more than one interesting address, of utilising the power of Niagara, appears about to be realised, at any rate in part; a large tract of land has been recently acquired, by a powerful American Association, about a mile distant from the Falls, with a view to the erection of mills for utilising the power, which it is also proposed to transmit to distant towns, and an International Commission, with Sir William Thomson at its head, and with Mascart, Turrettini, Coleman Sellers, and Unwin as members, will carefully consider the problems involved in the execution of this grand scheme.

The application of electric traction to water-traffic, first successfully demonstrated in 1883, is receiving gradual development, as illustrated by the considerable number of pleasure-boats which may now be seen on the Upper Thames during the boating season, and in connection with which Professor George Forbes proposed, at our meeting last year, that stations for charging the requisite cells, through the agency of water-power, should be established at the many weirs along the river, so as to provide convenient electric coaling-stations for the river pleasure-fleet.

Electrically-transmitted energy was first applied to haulage work in mines in Germany, by the firm of Siemens some years ago, and great progress has since been achieved herein on the Continent and in America. Comparatively little has been accomplished in this direction in England; but it is very interesting to note, on the present occasion, that the first successful practical application of electricity in this country to pumping and underground haulage-work was made in 1887 in this neighbourhood, at the St. John's Colliery at Normanton, where an extensive installation, carried out by Mr. Immisch, so well known in connection with electric launches, is furnishing very satisfactory results in point of economy and efficiency. The gigantic installations existing for the same purposes in Nevada and California afford remarkable indications of the work to be accomplished in the future by electrically-transmitted energy.

Among the many subjects of importance studied by Joule, with the originality and thoroughness characteristic of his work, was the application of voltaic electricity to the welding and fusion of metals. Thirty-four years ago he published a most suggestive paper on the subject, in which, after dealing with the difficulties attending the operation of welding, and of the interference of films of oxide, formed upon the highly heated iron surfaces, with the production of perfect welds either under the hammer or by the methods of pressure (of which he then predicted the application to large masses of forged iron), he refers to the possibility of applying the calorific agency of the electric current to the welding of metals, and describes an operation witnessed by him in the laboratory of his fellow-labourer, Thomson, of fusing together a bundle of iron wires by transmitting through them, when imbedded in charcoal, a powerful voltaic current. Joule afterwards succeeded in uniting by fusion a number of iron wires with the employment of a Daniell battery, and in welding together wires of brass and steel, platinum and iron, &c. In discussing the question of the amount of zinc consumed in a battery for raising a given amount of iron to the temperature of fusion, he points out that the same object would probably be more economically attained by the use of a magneto-electric machine, which would allow the heat to be provided by the expenditure of mechanical force, developed in the first instance by the expenditure of heat; and he indicates the possibility of arranging machinery to produce electric currents which shall evolve one-tenth of the total heat due to the combustion of the coal used, so that 5,000 grains of coal applied through that agency would suffice for the fusion of one pound of iron. The successful practical realisation of Joule's predictions in regard to the application of electric currents, thus developed, to the welding of iron and steel, and to analogous operations, through the agency of the efficient machines devised by Professor Elihu Thomson, was demonstrated to the members of the Association by Professor Ayrton at Bath two years ago, and was shown upon a larger scale to visitors at the Paris Exhibition last year, and recently to highly interested audiences in London by our late President, Sir Frederick Bramwell. The latter demonstrated that the production of iron-welds by means of the Thomson-machines was accomplished nearly twice as rapidly as by expert craftsmen; the perfection of the welds being proved by the fact that the strength of bars broken by tensile strains at the welds themselves was about 92 per cent. of the strength of the solid metal. At the Crewe Works Mr. Webb is successfully applying one of these machines to a variety of welding-work. The rapidity with which masses of metal of various dimensions are raised by them to welding heat is quite under control; the heat is applied without the advent of any impurities, as from fuel, and the speed of execution of the welding operation reduces to a minimum the time during which the heated surfaces are liable to oxidise. With such practical advantages as these, this system of electric welding bids fair to receive many useful applications.

Another very simple system of electric welding, especially applicable to thin iron- and steel-sheets, hoops, &c., has been contemporaneously elaborated in Russia by Dr. Bernados, and is already being extensively used. The required heat at the surfaces to be welded is developed by connecting the metal with the negative pole of the dynamo-machine, or of a battery of accumulators, the circuit being completed by applying a carbon electrode to the parts to be heated; the reducing power of the carbon is said to preserve the heated metal surfaces from oxidation during the very brief period of their treatment. This mode of operation appears to have been practised upon a small scale, some years ago, by Sir William Siemens, to whom we also owe the first attempt to practically apply electric energy to the smelting of metals.

In his Address in 1882 he referred to some results attained with his small electrical furnace, and pointed out that, although electric energy could, obviously, not compete economically with the direct combustion of fuel for the production of ordinary degrees of heat, the electric furnace would probably receive advantageous application for the attainment of temperatures exceeding the limits (about 1800° C.) beyond which combustion was known to proceed very sluggishly. This prediction appears to have been already realised through the important labours of Messrs. Cowles, who some years ago attacked the subject of the application of electricity to the achievement of metallurgic operations with the characteristic vigour and fertility of resource of our Transatlantic brethren. After very promising preliminary experiments, they succeeded, in 1885, at Cleveland, Ohio, in maturing a method of operation for the production of aluminium-bronze, ferro-aluminium, and silicium-bronze, with results so satisfactory as to lead to the erection of extensive works at Lockport, N.Y., where three dynamo-machines, each supplying a current of about 3,000 Ampères, are worked by water-power, through the agency of 500 h.-p. turbines, eighteen electric furnaces being now in operation for the production of aluminium alloys. These achievements have led to the establishment of similar works in North Staffordshire, where a gigantic dynamo-machine has been erected, furnishing a current of 5,000 Ampères, with an E. M. F. of 50 to 60 volts. The arrangement of electrodes in the furnaces, the preparation of the furnace-charges (consisting of mixtures of aluminium-ore with charcoal and with the particular granulated metal with which the aluminium is to become alloyed at the moment of its elimination from the ore); the appliances for securing safety in dealing with the current from the huge dynamo-machine, and many other details connected with this new system of metallurgic work, possess great interest. Various valuable copper- and aluminium-alloys are now produced by adding to copper itself definite proportions of copper-alloy very rich in aluminium, the product of the electric furnace. The rapid production in large quantities of ferro-aluminium—which presents the aluminium in a form suitable for addition in definite proportions to fluid cast iron and steel—is another useful outcome of the practical development of the electric furnace by Messrs. Cowles.

The electric process of producing aluminium-alloys has, however, to compete commercially with their manufacture by adding to metals, or alloys, pure aluminium produced by processes based upon the method originally indicated by Oersted in 1824, successfully carried out by Wöhler three years later, and developed into a practical process by H. St. Claire Deville in 1854—namely, by eliminating aluminium from the double chloride of sodium and aluminium in the presence of a fluoride, through the agency of sodium. An analogous process, indicated in the first instance by H. Rose—namely, the corresponding action of sodium upon the mineral cryolite, a double fluoride of aluminium and sodium—has also been recently elaborated at Newcastle, where the first of these methods was applied, upon a somewhat considerable scale, in 1860, by Sir Lowthian Bell, but did not then become a commercial success, mainly owing to the costliness of the requisite sodium. As the cost of this metal chiefly determines the price of the aluminium, technical chemists have devoted their best energies to the perfection and simplification of methods for its production, and the success which has culminated in the admirable Castner process constitutes one of the most interesting of recent illustrations of the progress made in technical chemistry, consequent upon the happy blending of chemical with mechanical science, through the labours of the chemical engineer.

Those who, like myself, remember how, between forty and fifty years ago, a few grains of sodium and potassium were treasured up by the chemist, and used with parsimonious care in an occasional lecture-experiment, cannot tire of feasting their eyes on the stores of sodium-ingots to be seen at Oldbury as the results of a rapidly and dexterously executed series of chemical and mechanical operations.

The reduction which has been effected in the cost of production of aluminium through this and other processes, and which has certainly not yet reached its limit, can scarcely fail to lead to applications of the valuable chemical and physical properties of this metal so widespread as to render it as indispensable in industries and the purposes of daily life as those well-known metals which may be termed domestic, even although, and, indeed, for the very reason that, its association with many of these, in small proportion only, may suffice to enhance their valuable properties or to impart to them novel characteristics.

The Swedish metallurgist, Wittenström, appears to have been the first to observe that the addition of small quantities of aluminium to fused steel and malleable iron had the effect of rendering them more fluid, and, by thus facilitating the escape of entangled gases, of ensuring the production of sound castings without any prejudicial effect upon the quality of the metal. The excellence of the so-called Mitis castings, produced in this way, appears thoroughly established, and the results of recent important experiments seem to be opening up a field for the extensive employment of aluminium in this direction, provided its cost becomes sufficiently reduced. The valuable scientific and practical experiments of W. J. Keep, James Riley, R. Hadfield, Stead, and other talented workers in this country and the United States, are rapidly extending our knowledge in regard to the real effects of aluminium upon steel, and their causes. Thus, it appears to be already established that the modifications in some of the physical properties of steel resulting from the addition of that metal, are not merely ascribable to its actual entrance into the composition of the steel, but are due, in part, to the de-oxidation by aluminium of some proportion of iron-oxide which exists distributed through the metal, and prejudicially affects its fluidity when melted. In the latter respect, therefore, the influence exerted by aluminium, when introduced in small proportions into malleable iron and steel, appears to be quite analogous to that of phosphorus, silicium, or lead when these are added in small proportions to copper and certain of its alloys, the de-oxidation of which, through the agency of those substances, results in the production of sound castings of increased strength and uniformity. It is only when present in small proportion in the finished steel that aluminium increases the breaking strain and elastic limit of the product.

The influence of aluminium, when used in small proportion, upon the properties of grey and white cast iron is also of considerable interest, especially its effect in promoting the production of sound castings, and of modifying the character of white iron in a similar manner to silicium, causing the carbon to be separated in the graphitic form; with this difference—that the carbon appears to be held in solution until the moment of setting of the liquid metal, when it is instantaneously liberated, with the result that the structure of the cast metal and distribution of the graphite are perfectly uniform throughout.

The probable beneficial connection of aluminium with the industries of iron and steel naturally directs attention to the great practical importance, in the same direction, which is already possessed, and promises to be in increasing measure attained, by certain other metals which, for long periods succeeding their discovery, have either been only of purely scientific interest and importance, or have acquired practical value in regard to their positions in a few directions quite unconnected with metallurgy. Thus, great interest attaches to the influence of the metals manganese, chromium, and tungsten upon the physical properties of steel and iron.

The name of Mushet is most prominently associated with the history of manganese in its relations to iron and steel. Half a century ago David Mushet carried out very instructive experiments on the influence exerted upon the properties of steel by the presence of manganese; and to Robert Mushet we owe the invaluable experiments leading to his suggestion to use manganese in the production of steel by the Bessemer process, which at once smoothed the path to the marvellously rapid and extensive development of the applications of steel produced by that classic method, and subsequently by the open-hearth or Siemens-Martin process—a development which has recently received its crowning illustration in the completion of one of the grandest of existing triumphs of engineering science and constructive skill—the Forth Bridge.

Robert Hadfield has recently contributed importantly to our knowledge of the relations of manganese to iron. His systematic study of the subject has revealed some very remarkable variations in the physical properties of so-called manganese-steel, according to the proportions of manganese which it contains. Thus, while the existence in steel of proportions ranging from 0·1 up to about 2·75 per cent. improves its strength and malleability, it becomes brittle if that limit is exceeded, the extreme of brittleness being obtained with between 4 and 5 per cent. of manganese; if, however, the percentage is increased to not less than 7, and up to 20, alloys of remarkable strength and toughness are obtained. Castings of high manganese-steel, such as wheel-tyres, combine remarkable hardness with toughness. Even if the proportion of manganese is as high as 20 per cent. in a steel containing 2 per cent. of carbon, it can be forged; whereas it is very difficult to forge a steel of ordinary composition containing as much as 2·75 per cent. of carbon. Another remarkable peculiarity of the high manganese-steel is its behaviour when quenched in water. Instead of the heated metal being hardened and rendered brittle by the sudden cooling, like carbon-steel, its tensile strength and its toughness are increased; so that water-quenching is really a toughening process, as applied to the manganese-alloy; and an interesting feature connected with this is that, the colder the bath into which the highly-heated metal is plunged, the tougher is the product. The curious effect of manganese in reducing, and even destroying, the magnetic properties of iron was already noticed by Rinman nearly 120 years ago, and was examined by Bottomley in 1885; one result of Hadfield's important labours has been to place in the hands of such eminent physicists as Thomson, Barrett, John Hopkinson, and Reinold, materials for the attainment of most interesting information respecting the electrical and other physical characteristics of manganese-steel. Hopkinson, from experiments with a sample of steel containing 12 per cent. of manganese, estimated that not more than 9 out of the 86 per cent. of the iron composing the mass was magnetic, and he considered that the manganese entered into that which must, for magnetic purposes, be regarded as the molecule of iron, completely changing its properties, a fact which must have great significance in any theory regarding the nature of magnetisation. The great hardness of manganese-steel, and the consequent difficulty of dealing with it by means of cutting-tools, constitute at present the chief impediments to its technical applications in many directions; but where great accuracy of dimensions is not required, and where great strength is an essential, it is already put to valuable uses.

The importance of manganese in connection with the metallurgy of iron and steel is in a fair way of finding its rival in that of the metal chromium, the employment of which, as an alloy with steel, was first made the subject of experiment in 1821, by Berthier. He was led by the important experiments of Faraday and Stoddart, then just published, to endeavour to alloy chromium with steel, and obtained good results by fusing steel together with a rich alloy of chromium and iron, so as to introduce about 15 per cent. of the former into the metal. Further small experiments were made the year following, by Faraday and Stoddart, in the same direction; but chrome-steel appears to have been first produced commercially at Brooklyn, N.Y., sixteen years ago. Ten years later its manufacture had become developed in France, and the varieties of chrome-steel produced in the Loire district now receive important and continually-extending applications, because they combine comparative hardness and high tenacity with but little loss in ductility, and acquire great closeness of structure when tempered.

The influence of chromium upon the character of steel differs in several marked respects from that exercised by manganese; thus, chrome-steels weld badly, or not at all, whereas manganese-steels weld very readily, and work under the hammer better than ordinary carbon-steel. Again, the remarkable influence of manganese upon the magnetic properties of steel and iron is not shared by chromium. Chrome-steel has for some time been a formidable rival of the very highest qualities of carbon-steel produced for cutting-tools, and of the valuable tungsten-steel which we owe to Robert Mushet. The great hardness, high tenacity, and exceeding closeness of structure possessed by suitably-tempered steel containing not more than from 1 to 1·5 per cent. of chromium, and from 0·8 to 1 per cent. of carbon, renders this material invaluable for war purposes: cast projectiles, when suitably tempered, have penetrated compound steel- and-iron plates over 9 inches in thickness, such as are used upon armoured ships of war, without even sustaining any important change of form. The proper tempering of these projectiles necessitates their being produced hollow; their cavities or chambers are only of small capacity, but the charge of violent explosive which they can contain, and which can be set into action without the intervention of fuse or detonating appliance, suffices to tear these formidable punching-tools into fragments as they force their way irresistibly through the armoured side of a ship, and to violently project those fragments in all directions, with fearfully destructive effects. The employment of chromium as a constituent of steel plates used for the protection of ships of war is already being entered upon, and the influence exerted by the presence of that metal in small quantities in steel employed in the construction of guns is also at present a subject of investigation. At Crewe, Mr. F. Webb has for some time past used chromium, with considerable advantage, in the production of high-quality steels for railway requirements.

The practical results attained by the introduction of copper and of nickel as components of steel have also recently attracted much attention. At the celebrated French Steel Works of M. Schneider, at Creuzot, the addition of a small percentage of copper to steel used for armour-plates and projectiles is practised, with the object of imparting hardness to the metal without prejudice to its toughness. James Riley has found that the presence of aluminium in very small quantities facilitates the union of steel with a small proportion of copper, and that the latter increases the strength but does not improve the working qualities of steel. With nickel, Riley has obtained products analogous in many important respects to manganese steel; the remarkable differences in the physical properties of the manganese alloys, according to their richness in that metal, are also shared by the nickel alloys, some of which possess very valuable properties; thus, it has been shown by Riley that a particular variety of nickel-steel presents to the engineer the means of nearly doubling boiler-pressures, without increasing weight or dimensions. He has, moreover, found the co-existence of manganese in small quantity with nickel in the alloy to contribute importantly to the development of valuable characteristics.

The careful study of the alloys of aluminium, chromium, manganese, tungsten, copper, and nickel, with iron and with steel, so far as it has been carried, with especial reference to the influence which they respectively exercise upon the salient physical properties of those materials, even when present in them in only very small proportions, has demonstrated the importance of a more searching or complete application of chemical analysis, than hitherto practised, to the determination of the composition of the varieties of steel which practical experience has shown to be peculiarly adapted to particular uses. It appears, indeed, not improbable that certain properties of these, hitherto ascribed to slight variations in the proportion or the condition of the constituent carbon, or in the amounts of silicium, phosphorus, and manganese which they contain, may sometimes have been due to the presence in minute quantities of one or other of such metals as those named, and to their influence, either direct or indirect, in modifying or counteracting the effects of the normal constituents of steel. The important part now played by manganese in steel manufacture is an illustration of the comparatively recent results of research, and of practical work based on research, in these directions, and the effects of the presence in steel of only very small quantities of some of the other metals named are already, as I have pointed out, being similarly understood and utilised.

Such systematic researches as those upon which Osmond, Roberts-Austen, and many other workers have been for some time past engaged, may make us acquainted with the laws which govern the modifications effected in the physical characteristics of metals by alloying these with small proportions of other metals. The suggestion of Roberts-Austen, that such modifications may have direct connection with the periodic law of Mendeleeff, explaining the causes of specific variations in the properties of iron and steel, has been followed up energetically by Osmond, who has experimentally investigated the thermal influence upon iron of the elements phosphorus, sulphur, arsenic, boron, silicium, nickel, manganese, chromium, copper, and tungsten. He regards his results as being quite confirmatory of the soundness of Roberts-Austen's suggestion, as they demonstrate that foreign elements having atomic volumes lower than iron tend to make it assume or preserve the particular molecular form in which it has itself the lowest atomic volume, while the converse is the case for the foreign elements of high atomic volume.

An analogous influence was found to be exerted by those two groups of elements upon the permanent magnetisation of steel.

Captivating as such deductions are, those who have devoted much attention to the practical investigation of iron, steel, and other metals, cannot but feel that much caution has to be exercised in drawing broad conclusions from the results of such researches as these. Like the investigations recently made with the object of ascertaining the condition in which carbon exists in steel, and the part played by it in determining the modifications in the properties developed in that material by the influences of temperature and of work done upon it, they are surrounded by formidable difficulties, arising from the practical impossibility of altogether eliminating the disturbing influences of minute quantities of foreign elementary bodies, co-existing, in the metal operated upon, with those whose effects we desire to study. Certain it is, however, that by acquiring an accurate acquaintance with the composition of varieties of iron and steel exhibiting characteristic properties; by persevering in the all-important work of systematic practical examination of the mechanical and physical peculiarities developed in iron and steel of known composition by their association with one or more of the rarer metals in varied proportions, and by the further prosecution of chemical and physical research in such directions as those which have already been fruitful of most instructive results, such talented labourers as Chernoff, Osmond, Roberts-Austen, Barus and Stroudal, Hadfield, Keep, James Riley, Stead, Turner, and others, cannot fail to contribute continually to the development of improvements equalling in importance those already attained in the production, treatment, and methods of applying cast iron, malleable iron, and steel, or alloys equivalent to steel in their qualities.

The causes of the variations in the physical properties of steel produced by the so-called hardening, annealing, and tempering processes were for very many years a fruitful subject of experimental inquiry, as well as of theoretical speculation with regard to the condition in which the carbon is distributed in steel, according to whether the metal is hardened or annealed, or in an intermediate, tempered state. Recent researches have made our knowledge in the latter direction fairly precise; as yet, however, we are only on the track of definite information respecting the nature and extent of connection between the physical peculiarities of steel in those different conditions and the established differences in the form and manner in which the carbon is disseminated through it.

The careful systematic study of the modifications developed in certain physical properties of iron and steel by gradual changes of temperature between fusion of the metal and the normal temperature, has shown those modifications to be governed by a constant law, and that at certain critical temperatures special phenomena present themselves. This important subject, which was so clearly brought before the Association last year in the interesting lecture of Roberts-Austen, has been, and is still being, pursued by accomplished workers, among whom the most prominent is F. Osmond. The phenomenon of recalescence, or the re-glowing of, or liberation of heat in, iron and steel at certain stages during the cooling process, first examined into by Barrett, appears to be the result of actual chemical combination between the metal and its contained carbon at the particular temperature attained at the time; while the absorption of heat, demonstrated by the arrest in rise of temperature during its continuous application to the metal, is ascribed to the elimination, within the mass, of carbon as an iron-carbide perfectly stable at low temperatures. The pursuit of a well-devised system of experimental inquiry into this subject has led Osmond to propound theories of the hardening and tempering of steel, which are at present receiving the careful study of physicists and chemists, and cannot fail to lead to further important advancement of our knowledge of the true nature of the influence of carbon upon the properties of iron.

Another important subject connected with the treatment of masses of steel, and with the influence exercised upon their physical characteristics by the processes of hardening and tempering, and by submitting them to oft-repeated concussions or vibrations, or to frequent or long-continued strains, is the development and maintenance, or gradual disappearance, of internal stresses in the masses—one of the many important subjects to which attention was directed by Dr. Anderson, the Director-General of Ordnance Factories, in his very suggestive Address to the Mechanical Section last year. This question is one of especial interest to the constructor of steel guns, as the powers of endurance of these do not simply depend upon the quality of the material composing them, but are very largely influenced by the treatment which it receives at the hands of the gunmaker. Indeed, the highest importance attaches to the processes which are applied to the preliminary preparation of the individual parts used in constructing the gun, and to the putting together of these so as to ensure their being and remaining in the physical condition best calculated to assist each other in securing for the structure the power of so successfully resisting the heavy strains to which it has to be subjected, as to suffer little alteration other than that due to the superficial action of the highly-heated products of explosion of the charges fired in the gun. The development of internal strains in objects of steel, especially by the hardening and tempering processes, or by their exposure to conditions favourable to unequal cooling of different parts of the mass, has long been a subject of much trouble and of experimental inquiry in connection with many applications of steel. Systematic experiments of the kind commenced, about eighteen years ago, by the late Russian general Kalakoutsky, are now being pursued at Woolwich, with the objects of determining the nature and causes of internal stresses in steel gun-hoops and -tubes, and in shells, and of thereby establishing the proper course to be adopted for avoiding, lessening, or counteracting injurious stresses, on the one hand, and for setting up stresses beneficial to the powers of endurance of guns, on the other. One method of experiment pursued, with parts of guns, is to cut narrow hoops off the forgings, after a particular treatment, which are then cut right across at one place, it being observed whether, and to what extent, the resulting gaps open or close. This important subject has also been similarly investigated by my talented old friend and fellow-worker, the President this year of the Mechanical Section, Captain Andrew Noble, whose name in connection with the science and practice of artillery is familiar to us as household words.

The Crimean War taught Nations many lessons of gravest import, to some of which Sir Richard Owen took occasion to call attention most impressively in the Address delivered here, before the miseries of that war had become past history. The development of sanitary science, to which he especially referred, and which sprang from the bitter experience of that sad epoch, has had its parallel in the development of the science of artillery; but it would indeed be difficult to establish any parallelism between the benefits which even the soldier and the sailor have reaped from the great strides made by both these sciences. The acquisition of knowledge of the causes of the then hopelessness of gallant struggles which medical skill and self-sacrificing devotion made against the sufferings of the victims of battles and of fell diseases, as deadly as the cruellest implements of war; the application of that knowledge to the provision of the blessings of antiseptic treatment of wounds and to the intelligent utilisation of disinfectants and of other valuable preventive measures, to the supply of wholesome water, of wholesome food in campaigning, of sensible clothing, and of wholesome air in hospitals, barracks, and ships—these are some few of the benefits which the soldier and the sailor have derived from the development of sanitary science, which was so powerfully stimulated by the terrible lessons learned during the long-drawn-out siege of Sebastopol; and it is indeed pleasant to reflect that there has been, for years past, most wholesome competition between Nations in the enlargement of those benefits, and their dissemination among the men whose vocation it is to slay and be slain. The periodical International Congresses on Hygiene and Demography, of which we shall cordially welcome next year's assemblage in London, and whose members will deplore the absence from among them of the veteran Nestor in the science and practice of hygiene, Sir Edwin Chadwick, have afforded conclusive demonstration of the heartiness with which Nations are now co-operating with a view to utilise the invaluable results attained by the successful labourers in sanitary science.

What, on the other hand, shall we say of the benefits which sailors and soldiers, in the pursuit of their calling, derive from the ceaseless costly competition amongst Nations for supremacy in the possession of formidable artillery, violent explosives, quick-firing arms of deadly accuracy, and fearful engines which, unseen, can work wholesale destruction in a fleet? And what can we say of the benefits acquired by individual Countries in return for their continuous, and sometimes ruinous, expenditure in endeavouring to maintain themselves upon an equality with their neighbours in man-killing power? The conditions under which engagements by sea or land will in the future be fought have certainly become greatly modified from those of thirty-five years ago, and the duration of warfare, even between Nations in conflict who are on a fair equality of resources, must become reduced; but, as regards the results of a trial of strength between contending forces, similarly equipped, as they now will be, with the latest of modern appliances only varying in detail, these must, after all, depend, as of old, partly upon accident, favoured, perhaps, by a temporary superiority in equipment, partly upon the skill and military genius of individuals, and very much upon the characteristics of the men who fight the battles.

What really can be said in favour of the advances made in the appliances of war—and this is, perhaps, the view which in such a town as Leeds we should keep before our eyes to the exclusion of the dark side of the picture—is, that by continuous competition in the development of their magnitude, diversity, and perfection, the resources of the manufacturer, the chemist, the engineer, the electrician, are taxed to the uttermost, with the very important, although incidental, results, that industries are created or expanded and perfected, trades maintained and developed, and new achievements accomplished in applied science, which in time beneficially affect the advance of peaceful arts and manufactures. In these ways the expenditure of a large proportion of a country's resources upon material which is destroyed in creating destruction does substantially benefit communities, and tends to the accomplishment of such material progress by a Country as goes far to compensate its people for the sacrifices which they are called upon to incur for the maintenance of their dignity among Nations.

From this point of view, at any rate, it may interest members of the British Association for the Advancement of Science, and for the promotion of its applications to the welfare and happiness of mankind, to hear something of recent advances in one of the several branches of science in its applications to naval and military requirements with which, during a long and arduous official career, now approaching its close, I have become in some measure identified.

Since the Meeting of the Association in this town in 1858, the progress which has been made in the regulation of the explosive force of gunpowder, so as to adapt it to the safe development of very high energy in guns presenting great differences in regard to size and to the work which they have to perform, has been most important. The different forms of gunpowder which were applied to war-purposes in this and other countries, until within the last few years, presented comparatively few differences in composition and methods of manufacture from each other, and from the gunpowder of our ancestors. The replacement of smooth-bore guns by rifled artillery, which followed the Crimean War, and the great increase in the size and power of guns necessitated by the application of armour to ships and forts, soon called, however, for the pursuit of investigations having for their object the attainment of means for variously modifying the action of fired gunpowder, so as to render it suitable for artillery of different calibres whose power could not be effectively, or, in some instances, safely, developed by the use of the only kind of gunpowder then employed in English artillery of all calibres.

The means resorted to in the earlier of these investigations, and adhered to for many years, for controlling the violence of explosion of gunpowder, consisted exclusively in modifying the size and form, density and hardness, of the individual masses composing a charge, with the object of varying the rate of burning of those masses in a gun; it being considered that, as the proportions of ingredients generally employed very nearly correspond to those required for the development of the greatest chemical energy by the thoroughly-incorporated materials, the attainment of the desired results should be, if possible, effected rather by modifications of the physical and mechanical characters of gunpowder, than by variations of the proportions and chemical characters of its ingredients.

The varieties of powder from time to time introduced into artillery-service, as the outcome of investigations in this direction, were of two distinct types: the first of these consisted of further developments of the old granulated or corned powder, being produced by breaking up more or less highly-pressed slabs of the material into grains, pebbles, or boulders of approximately uniform size and shape. Gunpowders of this class, ranging in size from about 1,000 pieces to the ounce to about 6 pieces to the pound, have performed efficient service, and certain of them are still employed. The character of the other type is based upon the theoretical view that uniformity in the action of a particular gunpowder, when employed under like conditions, demands not merely identity in regard to composition, but also identity in form, size, density, and structure of the individual masses of which a charge consists. To approach the practical realisation of this view, equal quantities of one and the same mixture of ingredients, presented in the form of powder of uniform fineness and dryness, must be submitted to a particular pressure, for a fixed period, in moulds of uniform size, the surrounding conditions and subsequent manufacturing processes being as nearly as possible alike. Practical experience has, however, shown that uniformity in the ballistic properties of black powder can be even more readily secured by the thorough blending or mixing together of different products of manufacture, presenting some variations in regard to size, density, hardness, or other features, than by aiming at an approach to identity in the characters of the individual grains or masses.

When our attention was first actively directed to the modification of the ballistic properties of powder, the subject had already been to some extent dealt with, in the United States, by Rodman and Doremus, and the latter had proposed the employment, in heavy guns, of charges consisting of large pellets of prismatic form. While this prismatic powder, which was first used in Russia, was being perfected, and extensively applied there as well as in Germany and England, the production of powder-masses more suitable, by the comparatively gradual nature of their explosion, for the very large charges required for the heavy artillery of the present day, was actively pursued in Italy, and by our own Government Committee on Explosives, the outcome of exhaustive practical investigations being the very efficient Fossano powder, or *poudre progressif* of the Italians, and the boulder- and large cylindrical-powders produced at Waltham Abbey.

Researches carried out by Captain Noble and myself, some years ago, with a series of gunpowders presenting considerable differences in composition, indicated that decided advantages might be secured, for heavy guns especially, by the employment of such a powder as would furnish a comparatively very large volume of gas, its explosion being at the same time attended by the development of much less heat than in the case of ordinary black powder. In the course of these researches much light was thrown upon the causes of the wearing or erosive action of powder-explosions upon the inner surface of the gun, an action which, especially in the larger calibres of artillery, produces so serious a deterioration of the arm that the velocity of projection and accuracy of shooting suffer considerably, the wear being most considerable where the products of explosion, while under the maximum pressure, can escape between the projectile and the bore. The great velocity with which the very highly-heated gaseous and liquid (fused solid) products of explosion sweep over the heated surface of the metal, gives rise to a displacement of the particles composing the surface of the bore, which increases in extent as the latter becomes roughened, and thus opposes increased resistance; at the same time, the high temperature to which the surface is raised reduces the rigidity of the metal, and its consequent power of resisting the force of the gaseous torrent; and, lastly, some amount of chemical action upon the metal, by certain of the highly-heated, non-gaseous products of explosion, contributes towards an increase in the erosive effects. Experiments made upon a large scale by Captain Noble with powders of different composition, and with other explosives, have afforded decisive evidence that the explosive agent which furnishes the largest proportion of gaseous products, and the explosion of which is attended by the development of the smallest amount of heat, exerts least erosive action.

Some eminent German gunpowder-manufacturers, who were at this time actively engaged upon the production of a suitable powder for heavy guns, directed their attention, not merely to an alteration of the proportions of the ingredients, but also to a modification in the character of charcoal employed; the eventual result was the production of a new prismatic powder, composed of saltpetre in somewhat higher proportion than in normal black powder, and of a very slightly-burned charcoal of reddish-brown colour, quite similar to the *charbon roux* which Violette produced about forty years ago for use in sporting-powder, by the action of superheated steam upon wood or other vegetable matter. This brown prismatic powder (or 'cocoa powder') differs from black powder not merely in colour: it burns very slowly in the open air, and in guns its action is comparatively gradual and long-sustained. The products of its explosion are simple; as the powder contains saltpetre in large proportion relatively to the sulphur and charcoal, these become fully oxidised, and a relatively very large amount of water-vapour is produced, partly because of the comparatively high proportion of water in the finished powder, and partly from the large amount of hydrogen in the slightly-charred wood or straw used. The smoke from a charge of brown powder differs but little in volume from that of black powder, but it disperses much more rapidly, owing to the speedy absorption of the finely-divided potassium salts, forming the smoke, by the large proportion of water-vapour through which they are distributed.

This kind of powder has been substituted, with considerable advantage, for black powder in guns of comparatively large calibre, but it soon became desirable to attain even more gradual action in the case of the very large charges required for guns of the heaviest calibres, such as the 110-ton gun, from which shot of about 1,800 lb. weight are propelled by a powder-charge of 960 lb. Brown powder has therefore been modified in composition to suit these conditions; while, on the other hand, a powder intermediate in rapidity of action between black powder and the brown prism powder has been found more suitable than the former for use in guns of moderately large calibre.

The importance which machine-guns and comparatively large, quick-firing guns have assumed in the armament of ships, has made it very desirable to provide a powder for them which will produce comparatively little or no smoke, as their efficient employment becomes greatly limited when, after a very few rounds rapidly fired, with black powder, the objects, against which it is desired to direct the fire are more or less completely hidden by the interposed smoke. Hence much attention has of late been directed to the production of smokeless, or nearly smokeless, powders for naval use. At the same time, the views of many military authorities regarding the importance of dispensing with smoke in engagements on land, have also created a demand for smokeless powders suitable for field-artillery and for small-arms.

The properties of ammonium-nitrate of which the products of decomposition by heat are, in addition to water-vapour, entirely gaseous, have rendered it a tempting material to those who have striven to produce a smokeless powder; but its deliquescent character has been a formidable obstacle to its application as a component of a useful explosive agent. By incorporating charcoal and saltpetre in particular proportions with ammonium-nitrate, F. Gaus recently claimed to have produced an explosive material free from the hygroscopic character common to other ammonium-nitrate mixtures, and furnishing only permanently gaseous and volatile, or smokeless, products of explosion. These anticipations were not realised, but they led the talented German powder-maker, Mr. Heidemann, to produce an ammonium-nitrate powder possessing remarkable ballistic properties, and producing comparatively little smoke, which speedily disperses. It yields a very much larger volume of gas and water-vapour than either black or brown powder, and is considerably slower in action than the latter; the charge required to produce equal ballistic results is less, while the chamber-pressure developed is lower, and the pressures along the chase of the gun are higher, than with brown powder. No great tendency is exhibited by it to absorb moisture from an ordinarily dry, or even somewhat moist, atmosphere, but it rapidly absorbs water when the hygroscopic condition of the air approaches saturation, and this greatly restricts its use.

About five years ago reports began to reach us from France of the attainment of remarkable results with a smokeless powder employed with the repeating or magazine rifle then in course of adoption for military service, and of marvellous velocities obtained by the use of this powder, in specially constructed artillery of great length. As in the case of the explosive agent called *Mélinite*, the fabulously-destructive effects of which were much vaunted at about the same time, the secret of the nature of this smokeless powder was well preserved by the French authorities; it is now known, however, that more than one smokeless explosive has succeeded the original, and that the material at present in use with the Lebel repeating rifle belongs to a class of nitro-cellulose or nitro-cotton preparations, of which several have been made the subject of patents in England, and of which varieties are also being used in Germany and other countries.

A comparison between the chemical changes attending the burning or explosion of gunpowder, and of the class of nitro-compounds represented by gun-cotton, at once explains the cause of the production of smoke by the former, and of the smokelessness of the latter. Whilst the products of explosion of the nitro-compounds consist exclusively of gases and of water-vapour, gunpowder, being composed of a large proportion of saltpetre, or other metallic nitrate, mixed with charred vegetable matter and variable quantities of sulphur, furnishes products of which over 50 per cent. are not gaseous, even at high temperatures, and which are in part deposited as a fused solid—which constitutes the fouling in a firearm—and in part distributed in an extremely fine state of division through the gases and vapours developed by the explosion, thus giving to these the appearance of smoke as they escape into the air.

So far as smokelessness is concerned, no material can surpass *gun-cotton* (or other varieties of nitro-cellulose); but, even if the rate of combustion of the fibrous explosive in a firearm could be controlled with certainty and uniformity, its application as a safe propulsive agent is attended by so many difficulties that the non-success of the numerous early attempts to apply it to that purpose is not surprising. Those attempts, commencing soon after the discovery of gun-cotton in 1846, and continued many years later in Austria, consisted entirely in varying the density and mechanical condition of employment of the gun-cotton fibre. No difficulty was experienced in thus exercising complete control over the rapidity of burning in the open air; but when the material was strongly confined, as in the bore of a gun, such methods of regulating its explosive force were quite unreliable, as some slight unforeseen variation in its compactness or in the amount and disposition of the air-spaces in the mass, would develop very violent action. Much more promising results were subsequently obtained by me by reducing the fibre to a pulp, as in the ordinary process of making paper, and converting this into highly-compressed, homogeneous masses of the desired form and size. Some favourable results were obtained at Woolwich, in 1867–8, in field-guns, with cartridges built up of compressed gun-cotton variously formed and arranged, with the object of regulating the rapidity of explosion of the charge. But although comparatively small charges often gave high velocities of projection, without any indications of injury to the gun, the uniform fulfilment of the conditions essential to safety proved to be beyond absolute control, even in guns of small calibre; and military authorities not being, in those days, alive to the advantages which might accrue from the employment of an entirely smokeless explosive in artillery, experiments in this direction were not persevered in. At the same time, considerable success attended the production of gun-cotton cartridges for sporting purposes, the rapidity of its explosion being controlled by various methods; very promising results were also attained with the Martini-Henry rifle and a lightly-compressed pulped gun-cotton charge, of pellet-form, the uniform action of which was secured by simple means.

A nearly smokeless sporting-powder had, in the meantime, been produced by Colonel Schultze, of the Prussian Artillery, from finely-divided wood, converted after purification into a mildly explosive form of nitro-cellulose, and impregnated with a small portion of an oxidising agent. Subsequently this powder was produced in a granular form, and rendered considerably more uniform in character, and less hygroscopic; it then closely resembled the well-known E.C. sporting powder, which consists of a nitro-cotton reduced to pulp, incorporated with the nitrates of potassium and barium, and converted into grains through the agency of a solvent and a binding material. Both these powders produce very little smoke compared with black powder, but they do not compete with the latter in regard to accuracy of shooting, when used in military arms.

In past years both camphor and liquid solvents have been applied to the hardening of the surfaces of granulated or compressed masses of gun-cotton and of this class of its preparations, with a view to render them non-porous. In some smokeless powders of French, German, Belgian, and English manufacture, acetic ether and acetone have been also used, not merely to harden the granules or tablets of the explosive, but also to convert the nitro-cellulose, in the first instance, into a more or less gelatinous condition, so that it can readily be incorporated with other components and rolled, or spread into sheets, or pressed into moulds, or squirted into wires, rods, or tubes, while still in a plastic state. When the solvent has afterwards been removed, the hardened, horn-like, or somewhat plastic product is cut up into tablets, or into strips or pieces of suitable dimensions, for conversion into charges or cartridges.

Another class of smokeless powder, similar in physical characteristics to these nitro-cellulose powders, but containing nitro-glycerine as an important component, has been originated by Mr. Alfred Nobel, the well-known inventor of dynamite, and bears resemblance in its physical characteristics to another of his inventions, called blasting-gelatine, one of the most interesting of known violent explosive agents. When one of the lower products of nitration of cellulose is impregnated with the liquid explosive, nitro-glycerine, it gradually loses its fibrous nature, becoming gelatinised while assimilating the liquid; and the resulting product almost possesses the characters of a compound. This preparation, and certain modifications of it, have acquired high importance as blasting-agents more powerful than dynamite, and are possessed of the valuable property that their prolonged immersion in water does not separate from them any appreciable proportion of nitro-glycerine. The nitro-glycerine powder first produced by Mr. Nobel was almost perfectly smokeless, and developed very high energy, accompanied by moderate pressures at the seat of the charge; but it possessed certain practical defects, which led to the development of several modifications of that explosive and various improvements in manufacture. The relative merits of this class of smokeless powder, and of various kinds of nitro-cellulose powder, are now under careful investigation in this and other countries, and several more or less formidable difficulties have been met with in their application, in small-arms especially; these arise in part from the comparatively great heat they develop, which increases the erosive effects of the products of explosion, and in part from the more or less complete absence of solid products. The surfaces of the barrel and of the projectile being left clean, after the firing, are in a condition favourable to their close adhesion while the bullet is propelled along the bore, with the consequence that very greatly increased friction is established. The latter difficulty has been surmounted by more than one expedient, but always at the cost of absolute smokelessness.

Our knowledge of the results obtained in France and Germany with the use of smokeless powders in the new rifles and in artillery is somewhat limited; our own experiments have demonstrated that satisfactory results are attainable with more than one variety of them, not only in the new repeating-arm of our infantry, but also with our machine-guns, with field-artillery, and with the quick-firing guns of larger calibre which constitute an important feature in the armament of our Navy. The importance of ensuring that the powder shall not be liable to undergo chemical change detrimental to its efficiency or safety, when stored in different localities where it may be subject to considerable variations of temperature (a condition especially essential in connection with our own Naval and Military service in all parts of the world), necessitates qualities not very easily secured in an explosive agent consisting mainly of the comparatively sensitive nitro-compounds to which the chemist is limited in the production of a smokeless powder. It is possible, therefore, that the extent of use of such a material in our ships, or in our tropical possessions, may have to be limited by the practicability of fulfilling certain special conditions essential to its storage without danger of possible deterioration. If, however, great advantages are likely to attend the employment of a smokeless explosive, at any rate for certain Services, it will be well worth while to adopt such special arrangements as may be required for securing these without incurring special dangers; this may prove to be especially necessary in our ships of war, where temperatures so high as to be prejudicial even to ordinary black powder sometimes prevail in the magazines, consequent mainly upon the positions assigned to them in the ships, but which may be guarded against by measures not difficult of application.

The Press accounts of the wonderful performances of the first smokeless powder adopted by the French—which, it should be added, were in some respects confirmed by official reports of officers who had witnessed experiments at a considerable distance—engendered a belief that a very great revolution in the conduct of campaigns must result from the introduction of such powders. It was even reported very positively that noiselessness was one of the important attributes of a smokeless powder, and highly-coloured comparisons have in consequence been drawn in Service-periodicals, and even by some military authorities, between the battles of the past and those of the future: the terrific din caused by the firing of the many guns and the roar of infantry-fire, in heavy engagements, being supposed to be reduced to noise so slight that distant troops would fail to know in what direction their comrades were engaged, and that sentries and outposts would no longer be able to warn their comrades of the approaching foe by the discharge of their rifles. Military journals of renown, misled by such legendary accounts, chiefly emanating from France, referred to the absence of noise and smoke in battles as greatly enhancing the demands for skill and courage, and as surrounding a fight with mystery. The absence of recoil when a rifle was fired with smokeless powder was another of the marvels reported to attend the use of these new agents of warfare. It need scarcely be said that a closer acquaintance with them has dispelled the credit given to such of the accounts of their supposed qualities as were mythical, and a belief in which could only be ascribable to a phenomenal combination of credulity with ignorance of the most elementary scientific knowledge.

The extensive use which has been made in Germany of smokeless or nearly smokeless powder in one or two special military displays has, however, afforded interesting indications of the actual changes likely to be wrought in the conditions under which engagements on land will be fought in the future, provided these new explosives thoroughly establish and maintain their positions as safe and reliable propelling agents. Although the powder adopted in Germany is not actually smokeless, the almost transparent film of smoke produced by independent rifle-firing with it is not visible at a distance of about 300 yards; at shorter distances it presents the appearance of a puff from a cigar. The most rapid salvo-firing by a large number of men does not have the effect of obscuring them from distant observers. When machine-guns and field-artillery are fired with the almost absolutely smokeless powder which we are employing, their position is not readily revealed to distant observers by the momentary vivid flash of flame and slight cloud of dust produced.

There now appears little doubt that in future warfare belligerents on both sides will alike be users of these new powders; the screening or obscuring effect of smoke will therefore be practically absent during engagements between contending forces, and while, on the one hand, the very important protection of smoke, and its sometimes equally important assistance in manœuvres, will thus be abolished, both combatants will, on the other hand, secure the advantages of accuracy of shooting and of the use of individual fire, through the medium of cover, with comparative immunity from detection. Such results as these cannot fail to affect, more or less radically, the principles and conditions under which battles have hitherto been fought. With respect to the Naval Service, it is especially for the quick-firing guns, so important for defensive purposes, that a smokeless powder has been anxiously looked for; by the adoption of such a powder as has during the past year been elaborated for our artillery, should experience establish its reliability under all Service conditions and its power to fulfil all reasonable requirements in regard to stability, these guns will not only be used by our ships under conditions most favourable to their efficiency, but their power will also be very importantly increased.

The ready and safe attainment of very high velocities of projection through the agency of these new varieties of explosive agents, employed in guns of suitable construction, would appear at first sight to promise a very important advance in the power of artillery; the practical difficulties attending the utilisation of these results are, however, sufficiently formidable to place, at any rate at present, comparatively narrow limits upon our powers of availing ourselves of the advantages in ballistics which they may present. The strength of the gun-carriages and the character of the arrangements used for absorbing the force of recoil of the gun need considerable modifications, not easy of application in some instances; greater strength and perfection of manufacture are imperative in the case of the hollow projectiles or shells to be used with charges of a propelling agent, by the firing of which in the gun they may be submitted to comparatively very severe concussions; the increased friction to which portions of the explosive contents of the shell are exposed by the more violent setting back of the mass may increase the possibility of their accidental ignition before the shell has been projected from the gun; the increase of concussion to which the fuse in the shell is exposed may give rise to a similar risk consequent upon an increased liability to a failure of the mechanical devices employed for preventing the igniting arrangement, designed to come into operation only upon the impact or graze of the projected shells, from being set into action prematurely by the shock of the discharge; lastly, the circumstance, that the rate of burning of the time-fuse which determines the efficiency of a projected shrapnel shell is materially altered by an increase in the velocity of flight of the shell, also presents a source of difficulty.

The fallibility of even the most simple forms of fuse, manufactured in very large numbers, although it may be remote, must always engender a feeling of insecurity, when shells are employed containing an explosive agent of the class which, in recent years, it has been sought, by every resource of ingenuity, combined with intimate knowledge of the properties of these explosives, to apply as substitutes for gunpowder in shells, on account of their comparatively great destructive power.

One of the first uses, for purposes of warfare, to which it was attempted to apply gun-cotton, was as a charge for shells. But even when this was highly compressed, and accurately fitted the shell-chamber, with the intervention only of a soft packing between the surfaces of explosive and of metal, to guard against friction between the two upon the shock of the discharge, no security was attainable against the ignition of the comparatively sensitive explosive by friction established within its mass at the moment when the shell is first set in motion. By the premature explosion of a shell charged with gunpowder, no important injury is inflicted upon the gun, but a similar accidental ignition of a gun-cotton charge must almost inevitably burst the arm. The earlier attempts to apply gun-cotton as a bursting-charge for shells were several times attended by very disastrous accidents of this kind; but the fact, afterwards discovered, that wet compressed gun-cotton, even when containing sufficient water to render it quite uninflammable, can be detonated through the agency of a sufficiently powerful charge of fulminate of mercury, or of a small quantity of dry gun-cotton imbedded within it, has led to the perfectly safe application of gun-cotton in shells, provided the fuse, through the agency of which the initiative detonating agent in the shell comes into operation, is secure against any liability to premature ignition when the gun is fired. Many successful experiments have been made with shells thus charged with wet gun-cotton, which is now recognised as a formidable destructive agent applicable in shells with much less risk of casualty than attends the use of many other of the violent explosive bodies which it has become fashionable, in professional parlance, to designate as 'high explosives.'

Many devices and arrangements, more or less ingenious and complicated, have been schemed, especially in the United States, for applying preparations of the very sensitive liquid, nitro-glycerine, such as dynamite and blasting-gelatine, as charges for shells. Some of these consist in subdividing the charge by more or less elaborate methods; in others the shell is also lined with some soft elastic packing-material, and paddings of similar material are applied in the head and the base of the shell-chamber, with the object of reducing the friction and concussion to which the explosive is exposed when the projectile is first set in motion. Such arrangements obviously diminish the space available for the charge in the shell, and the best of them fail to render these explosives as safe to employ as wet gun-cotton. In order to avoid exposing shells loaded with such explosives to the concussion produced when propelling them by a powder-charge, compressed air has been applied as the propelling agent, and guns of special construction and very large dimensions, from which shells containing as much as 500 lb. of gun-cotton or dynamite are projected through the agency of compressed air, have recently been elaborated in the United States, where great expectations are entertained of the value, for war-purposes, of these so-called pneumatic guns.

A highly ingenious device for utilising a class of very powerful explosives in shells, without any risk of accident to the gun, was not long since brought forward by Mr. Grüsen, the well-known armour-plate and projectile manufacturer of Magdeburg. It consisted of a thoroughly efficient arrangement for applying the fact, first demonstrated by Dr. Sprengel, that mixtures of nitric acid of high specific gravity with solid or liquid hydrocarbons, or with the nitro-compounds of these, are susceptible of detonation, with development of very high energy. The two agents, of themselves non-explosive—nitric acid and the hydro-carbon, or its nitro-product—are separately confined in the shell; when it is first set in motion by the firing of the gun, the fracture of the receptacle containing the liquid nitric acid is determined by a very simple device; the two substances are then free to come into contact, and their very rapid mixture is promoted by the rotation of the shell, so that, almost by the time that it is projected from the gun, its contents, at first quite harmless, have become converted into a powerfully explosive mixture, ready to come into operation through the action of the fuse. Although safety appears assured by this system, the comparatively complicated nature of the contrivance, and the loss of space in the shell thereby entailed, place it at a disadvantage, especially since some other very violent explosive agents have come to be applied with comparative safety in shells.

Between four and five years ago intelligence first reached us of marvellously destructive effects produced by shells charged with an explosive agent which the French Government was elaborating. The reported results surpassed any previously recorded in regard to violently destructive effects and great velocity of projection of the fragments of exploded shells, and it was asserted that the employment of this new material, Mélinite, was unattended by the usual dangers incident to this particular application of violent explosive agents, an assertion scarcely consistent with accounts which soon reached us of several terrible calamities due to the accidental explosion of shells loaded with Mélinite.

Although the secret of the precise nature of Mélinite has been extremely well preserved, it transpired ere long that extensive purchases were made in England, by or for the French authorities, of one of the many coal-tar derivatives which for some years past has been extensively manufactured for tinctorial purposes, but which, although not itself classed among explosive bodies until quite lately, had long before been known to furnish, with some metals, more or less highly explosive combinations, some of which had been applied to the production of preparations suggested as substitutes for gunpowder.

The product of destructive distillation of coal from which, by oxidation, this material is now manufactured, is the important and universally-known antiseptic and disinfectant, carbolic acid, or phenol. Originally designated carbazotic acid, the substance now known as picric acid was first obtained in small quantities as a chemical curiosity by the oxidation of silk, aloes, &c., and of the well-known blue dye indigo, which thus yielded another dye of a brilliant yellow colour. To the many who may regard this interesting phenol-derivative as a material concerning the stability and other properties of which we have little knowledge, it will be interesting to learn that it has been known to chemists for more than a century. It was first manufactured in England for tinctorial purposes by the oxidation of a yellow resin (*Xanthorrhœa hastilis*), known as Botany Bay gum. Its production from carbolic acid was developed in Manchester in 1862, and its application as a dye gradually extended, until, in 1886, nearly 100 tons were produced in England and Wales.

Although picric acid compounds were long since experimented with as explosive agents, it was not until a very serious accident occurred, in 1887, at some works near Manchester where the dye had been for some time manufactured, that public attention was directed in England to the powerfully explosive nature of this substance itself. The French authorities appear, however, to have been at that time already engaged upon its application as an explosive for shells. It is now produced in very large quantities at several works in Great Britain, and it has been extensively exported during the last four years, evidently for other than the usual commercial purposes. Large supplies of phenol, or carbolic acid, have, at the same time, been purchased in England for France, and lately for Germany, doubtless for the manufacture of picric acid, very extensive works having been established for its production in both those countries. It has been made the subject of experiment by our military authorities, and its position has been well established as a thoroughly stable explosive agent, easily manufactured, comparatively safe to deal with, and very destructive when the conditions essential for its detonation are fulfilled.

The precise nature of Mélinite appears to be still only known to the French authorities: it is asserted to be a mixture of picric acid with some material imparting to it greater power; but accounts of accidents which have occurred even quite recently in the handling of shells charged with that material appear to show that, in point of safety or stability, it is decidedly inferior to simple picric acid. Reliable as the latter is, in this respect, its employment is, however, not unattended with the difficulties and risks which have to be encountered in the use, in shells, of other especially violent explosives. Future experience in actual warfare can alone determine decisively the relative value of violent explosive agents, like picric acid or wet gun-cotton, and of the comparatively slow explosive, gunpowder, for use in shells; it is certain, however, that the latter still presents distinct advantages in some directions, and that there is no present prospect of its being more than very partially superseded as an explosive for shells.

With regard to submarine mines and locomotive torpedoes, such as those marvels of ingenuity and constructive skill, the Whitehead and Brennan torpedoes, the important progress recently made in the practical development of explosive agents has not resulted in the provision of a material which equals wet compressed gun-cotton in combining with great destructive power the all-important essential of safety to those who have to deal with these formidable weapons and to man the small vessels destined to perform the very hazardous service of attacking ships of war at short distances by means of locomotive torpedoes.

Although the subject of the development of explosive force for purposes of war has of late received from workers in applied science, from seekers of patentable inventions, and even from the public generally, a somewhat predominating share of attention, considering that we congratulate ourselves upon the enjoyment of a period of profound peace, yet the production of new explosive agents for mining and quarrying purposes, which present or lay claim to points of superiority over the well-established blasting-agents, has been by no means at a standstill. For many years the main object sought to be achieved in this direction was to surpass, in power or adaptability to particular classes of work, the well-known preparations of nitro-glycerine and gun-cotton, which, during the past twenty years, have been formidable competitors and, in many directions, absolutely successful rivals of black powder. It is both interesting and satisfactory to note, however, that this object has of late, and especially since the publication of the results of labours of English and foreign Commissions on the causes of mine-accidents, been prominently associated with endeavours to solve the important problems of combining, in an explosive agent, efficiency in point of power with comparative non-sensitiveness to explosion by friction or percussion, and of securing its effective operation with little or no accompaniment of projected flame. Safety-dynamites, flameless explosives, water-cartridges, and other classes of materials and devices connected with the getting of coal, the quarrying of rock, or the blasting of minerals, have claimed the attention of those who guide the miner's work; in some of these directions the practical results obtained have been beyond question important, and, indeed, conclusive as regards the great diminution of risks to which men need be exposed in those coal-mines where the ordinary use of explosives, although not altogether inadmissible, may at times be attended with danger. It is to be feared that those results are still far from receiving the amount of application which might reasonably be hoped for; but, at any rate, there are, among the extensive mining districts where the employment of explosives in connection with the getting of coal cannot be dispensed with, several of importance where the use of gunpowder has almost entirely given place to the adoption of blasting-agents or methods of blasting, the employment of which is either not, or only very exceptionally, attended by the projection of flame or incandescent matter into the air where the shot is fired.

The mining public is especially indebted to German workers for much of the success which has been obtained in this direction, and also to the eminent French authorities, Mallard and Le Chatelier, for their thorough theoretical and practical investigations bearing upon the prevention of accidental ignition of fire-damp during blasting operations. Having arrived at the conclusion that fire-damp- and air-mixtures are not ignited by the firing of explosive preparations which develop by their detonation temperatures lower than 2220° C., they found that ammonium-nitrate, although in itself susceptible of detonation, does not develop a higher temperature than 1130° C., while the temperature of detonation of nitro-glycerine and gun-cotton are, respectively, 3170° and 2636°. Hence the admixture of that salt with nitro-glycerine or gun-cotton in sufficient proportion to reduce the temperature of detonation to within safe limits should allow of the employment of those explosive agents in the presence of fire-damp mixtures without risk of accident, and the practical verification of this conclusion has led to the effective use of such mixtures as safe blasting-agents in coal.

Those who have been content to labour long and arduously with the objects steadily in view of advancing our knowledge of the causes of mine-accidents and of developing resources and measures for removing or combating those causes, can cherish the conviction that recent legislation in connection with coal-mines, based upon the results of those labours, has been already productive of decided benefits to the miner, even although it has fallen short of what might reasonably have been hoped for as an outcome of the very definite results and conclusions arrived at by the late Royal Commission on Accidents in Mines (in the recent much-lamented death of whose universally respected chairman, my late esteemed friend and colleague, Sir Warington Smyth, the scientific world has sustained the loss of an ardent worker, and the miner, of an invaluable friend).

The fearful dangers arising from the accumulation of inflammable dust in coal-mines, and the equality of mine-dust with fire-damp in its direful power of propagating explosions, which may sometimes even be, in the first instance, established chiefly or entirely through its agency, have now been long recognised as beyond dispute; and it is satisfactory to know that permission to fire shots in mine-workings which are dry and dusty has, by recent legislation, been made conditional upon the previous laying of the dust by effective watering. In some mining districts, moreover, the purely voluntary practice has been extensively adopted, by mine-owners, of periodically watering the main roads in dry and dusty mines, or of frequently discharging water-spray into the air in such roads, which must tend greatly to reduce the possible magnitude of the disastrous results of a fire-damp- or dust-explosion in any part of the mine-workings.

The encouragement given to the application of the combined resources of ingenuity, mechanical skill, and knowledge of scientific principles, through the elaborate, but thoroughly practical, comparative trials to which almost every variety of safety-lamp has, during the last few years, been submitted by competent and conscientious experimenters, has resulted in the provision of lamps to the hand of the miner which combine the essential qualities of safety, under the most exceptionally severe conditions, with good illuminating power, simplicity of construction, lightness, and moderate cost. Very important progress has also been made, since the first appointment of the late Accidents in Mines Commission, towards the provision of thoroughly serviceable and safe portable electric lamps for use in mines. Of those which have already been in the hands of the miners, several have fairly fulfilled his requirements as regards size, weight, and good illuminating power of sufficient duration; but much still remains to be accomplished with respect to durability, simplicity, thorough portability, and cost, before the selfcontained electric lamp can be expected to compete successfully with the greatly improved miners' lamps which are now in use, or available.

The recent legislation in connection with mines is certainly deficient in any sufficiently decisive measure for excluding from mine-workings certain forms of lamps which, while fairly safe in the old days of sluggish ventilation, are unsafe in the rapid air-currents now frequently met with in mines; it is, however, very satisfactory to know that the strong representations on this subject made by the late Commission, combined with force of example and with the conclusive demonstration, by exhaustive experiments, of the superiority of other lamps, have led within the last two years to the very general abandonment of the unprotected Davy, Clanny, and Stephenson lamps in favour, either of simple, safe modifications of these, or of other safe and efficient lamps, and that one possible element of danger to the miner has thus been eliminated, at any rate in many districts. In one important respect recent improved legislation has failed to effect a most desirable change, namely, in the substitution of safety-lamps for naked lights in workings where small local accumulations of fire-damp are discovered from time to time. There appears little doubt that one of the three fearful explosions which have occurred within the last twelve months—the catastrophe at Llanerch Colliery, near Pontypool—was caused by the continued employment of naked lights in a mine where inspection constantly revealed the presence of fire-damp. This explosion, and two other terrible disasters, at Mossfield Colliery, in Staffordshire, and at Morfa Colliery, near Swansea, which have occurred since the last meeting of the Association, may have seemed to weaken the belief that the operation of the recent Mines Regulation Act, which was based upon some of the results of seven years' arduous labour of the late Mines Commission, must have resulted in very substantial improvement in the management of mines and in the conduct of work by the men. Happily, however, there is a consensus of opinion among those most competent to judge—*i.e.* the Government Mine Inspectors—that very decided benefits have already accrued from the operation of the new Act. Although far from embodying all that the experienced mine-owners, miners, and scientific workers upon that Commission, as well as practical authorities in Parliament, concurred in regarding as reasonably adaptable, from the results of observation and experiment, to the furtherance of the safer working of mines, this Act does include measures, precautionary and preventive, of undeniable utility, well calculated to lessen the dangers which surround the miner, and to add to his personal comfort underground. We may hope, moreover, that the operation of the Act is paving the way to more comprehensive legislation in the near future; for it can scarcely be doubted, by the light of recent sad experience, that there are directions in which both masters and men still hesitate to adopt, of their own free will, measures or regulations, methods of working or appliances and precautions, which are calculated to be important additional safeguards against mine-accidents, and which are either left untouched, or only hesitatingly and imperfectly dealt with in the recent enactments.

My labours upon the late Mines Commission represent only one of several subjects in connection with which it has been my good fortune to have opportunities of rendering some slight public service in directions contrasting with one of the main functions of my career, by endeavouring to apply the results of scientific research to a diminution of the risks to which particular classes of the community, or the public at large, are exposed—of being sufferers by explosions, the results of accidents or other causes.

During the pursuit of bread-winning vocations, and even in ordinary domestic life, the conditions, as well as the materials, requisite for determining more or less disastrous explosions are often ready to hand, and their activity may be evoked at any moment through individual heedlessness or through pure accident. Steam, or gases confined under pressure, volatile inflammable liquids, combustible gases, or finely-divided inflammable solids, are now all well recognised as capable of assuming the character of formidable explosive agents; but with respect to the three last-named, it is only of late that material progress has been made towards a popular comprehension and appreciation of the conditions conducive to danger, and of those by the fulfilment of which danger may be avoided. Thus, the causes of explosions in coal-laden ships, together with the occurrence of spontaneous ignition in coal-cargoes, another fruitful source of disaster, were made the subject of careful inquiry some years ago by a Royal Commission, upon which I had the pleasure of working with the late Dr. Percy, whose invaluable labours for the advancement of metallurgic science will always be gratefully remembered. The light thrown by that inquiry upon the causes of those disasters, and upon the conditions to be fulfilled for guarding against the accumulations of fire-damp, gradually escaping from occlusion in coal, and of heat, developed by chemical changes occurring in coal-cargoes, has unquestionably led to an important reduction of the risks to which coal-laden ships are exposed. Subsequent official inquiries and experimental investigations, in which I took part with the late Sir Warington Smyth and some eminent naval officers, consequent upon the loss of H.M.S. 'Doterel' through the accidental ignition of an explosive mixture of petroleum spirit-vapour and air (and other calamities in warships originating with the gradual emission of fire-damp from coal), have resulted in the adoption of efficient arrangements for ventilating all spaces occupied by, and contiguous to, the large supplies of fuel which these vessels have to carry.

The thorough investigation, by Rankine and others, of the causes of explosions in flour-mills, which in years past were so frequent and disastrous, has secured the adoption of efficient measures for diminishing the production, and the dissemination through channels and other spaces in the mills, of explosive mixtures of flour-dust and air, and for guarding against their accidental ignition. The numerous terrible accidents caused by the formation and accidental ignition of explosive mixtures of inflammable vapour and air in ships carrying cargoes of petroleum stored in barrels or in tanks, have, by the investigations to which they have given rise, led to the indication of effective precautionary measures for guarding against their recurrence. Again, the many distressing accidents, frequently fatal, which have attended the domestic use of those valuable illuminants, petroleum and mineral oils of kindred character, have been made the subject of exhaustive investigations, which have demonstrated that these disasters may readily be prevented by the employment of lamps of proper construction, and by the observance of very simple precautions by the users of them; and a recent official inquiry which I have conducted with Mr. Boverton Redwood has furnished most gratifying proof that very substantial progress has been made within the last few years by lamp-manufacturers in the voluntary adoption of such principles of construction as we had experimentally demonstrated to be essential for securing the safe use of mineral oils in lamps for lighting and heating purposes, the employment of which has, within a brief period, received enormous extension in this and other countries.

The creation and rapid development of the petroleum industry has, indeed, furnished one of the most remarkable illustrations which can be cited of industrial progress during the period which has elapsed since the British Association last met in Leeds. One year after that meeting, viz., on August 28, 1859, the first well, drilled in the United States with the object of obtaining petroleum, was successfully completed, and the rate of increase in production in the Pennsylvania oil-fields during the succeeding years is shown by the following figures:—

In 1859, 5,000 barrels (of forty-two American gallons) were produced. In the following year the production increased to 500,000 barrels; while in the next year (1861) it exceeded 2,000,000 barrels, at which figure it remained, with slight fluctuations, until 1865. The supply then continued to increase gradually, until, in 1870, it reached nearly 6,000,000 barrels; while in 1874 it amounted to nearly 11,000,000 barrels. In 1880 it amounted to over 26,000,000 barrels, and in 1882 it reached 31,000,000. Since then the supply furnished by the United States has fallen somewhat, and last year it amounted to 21,500,000 barrels. The production of crude petroleum in the Pennsylvanian fields, large as it has been, has not, however, kept pace with the consumption, for we find that the accumulated stocks, which on December 31, 1888, amounted to over 18,000,000 barrels, had become reduced to about 11,000,000 barrels at the close of last year. At this rate the surplus stock above ground will have vanished by the end of the current year. In addition to the petroleum raised in Pennsylvania, there is now a very large production in the State of Ohio; but this has not as yet been employed as a source of lamp-oil; it is, however, transported by pipe line in great quantities to Chicago, for use as liquid fuel in industrial operations.

A few years after the development of the United States petroleum-industry, the production of crude petroleum in Russia also began to extend very rapidly. For more than 2,500 years Baku, on the borders of the Caspian Sea, has been celebrated for its naphtha springs and for the perpetual flames of the Fire Worshippers, fed by the marvellous subterranean supplies of natural gas. To a limited extent neighbouring nations appear to have availed themselves of the vast supplies of mineral oil at Baku during the past one thousand years. By the thirteenth century the export of the crude oil had already become somewhat extensive, but the production of petroleum from it by distillation is of comparatively recent date. In 1863 the supplies of petroleum from the Baku district amounted to 5,018 tons; they increased to somewhat more than double during the succeeding five years. In 1869 and following three years the production reached about 27,000 tons annually, and in 1873 it was about 64,000 tons; three years later, 153,000 tons were produced, and in the following five years there was a steady annual increase, until, in 1882, the production amounted to 677,269 tons; in 1884 it considerably exceeded 1,000,000 tons, and last year it amounted to about 3,300,000 tons. The consumption of crude petroleum as fuel for locomotive purposes has, moreover, now assumed very large proportions in Russia, and many millions of gallons are annually consumed in working the vast system of railways on both sides of the Caspian Sea.

The imported refined petroleum used in this country in lamps for lighting, heating, and cooking, was exclusively American until within the last few years, but a very large proportion of present supplies comes from Russia. The imports of kerosene into London and the chief ports of the United Kingdom during 1889 amounted to 1,116,205 barrels of United States oil, and 771,227 barrels of Russian oil. During the same period the out-turn of mineral oil for use in lamps by the Scottish Shale Oil Companies probably amounted to about 500,000 barrels.

Another important feature connected with the development of the petroleum industry is the great extent to which the less volatile products of its distillation have replaced vegetable and animal oils and fats for lubricating purposes in this and other countries. The value of petroleum as a liquid fuel and as a source of gas for illuminating purposes has, moreover, been long since recognised, and it is probable that one outcome of the attention which is now being given to the hitherto unworked deposits of petroleum in the East and West Indies, South America, and elsewhere, will be a very large increase in its application to these purposes. In the East Indies there are vast tracts of oil-fields in Burmah, Baluchistan, Assam, and the Punjab. The native Rangoon oil industry is one of great antiquity, although the oil was only used in the crude condition until about thirty-five years ago, at which time Dr. Hugo Müller, with the late Warren De la Rue, whose many-sided labours and generous benefactions have so importantly contributed to the advancement of science, made valuable researches on the products furnished by crude oil imported from Rangoon. The resources of the oil-fields of Upper Burmah, especially of the district of Yenangyoung (or *creek of stinking water*), have since then been developed by British enterprise, and have attained to considerable importance since our annexation of Upper Burmah.

The great extension of the petroleum trade is gradually leading to very important improvements in the system of transport of the material over water and on land. Until recently this has been carried out entirely in barrels and tin cases; the consequent great loss from leakage and evaporation, accompanied by risk of accident, is now becoming much reduced by the rapidly-increasing employment of tank-steamers, which transport the oil in bulk. Tank railway-wagons have for some time past been in use in Russia, and there is prospect of these and of tank-barges being adopted here for the distribution of the oil; while in London, the practice is already spreading gradually of distributing supplies to tradesmen from tank road-wagons. Some considerable doubt as to whether the risk of accident has not rather been altered in character than actually reduced by the new system of transport, has not unnaturally been engendered in the public mind by the occurrence within a comparatively short period of several serious disasters during the discharge of cargoes from tank-vessels. The memorable explosion which took place in October 1888, on board the 'Ville de Calais,' in Calais Harbour, with widespread destructive effects, was followed by a similarly serious explosion in the 'Fergusons,' at Rouen last December, and, more recently, by a fire of somewhat destructive character at Sunderland, resulting from the discharge into the river of petroleum-residues from a ship's tanks. In all these cases the petroleum was of a nature to allow inflammable vapour to escape readily from the liquid, so that an explosive mixture could be rapidly formed by its copious diffusion through the air. No similar casualty has been brought to notice as having happened to tank-ships carrying petroleum oil of which the volatility is in accordance with our legal requirements, and this points to the prudence of restricting the application of the tank system to the transport and distribution of such petroleum as complies with well-established conditions of safety.

Another most remarkable feature connected with the development of the petroleum industry is presented by the utilisation, within the last few years, of the vast supplies of natural inflammable gas furnished by the oil-fields.

In America this remarkable gas-supply was for a long time only used locally, but before the close of 1885 its conveyance to a distance by pipes, for illuminating and heating purposes, had assumed large proportions, one of the companies in Pittsburgh having alone laid 335 miles of pipes of various sizes, through which gas was supplied equivalent in heating value to 3,650,000 tons of coal per annum. Since then the consumption in and around Pittsburgh has probably been at least tripled. At the close of 1886 six different companies were conveying natural gas by pipes to Pittsburgh from 107 wells; 500 miles of pipe, ranging in diameter from 30 inches to 3 inches, were used by these companies, 232 miles of which were laid within Pittsburgh itself. The Philadelphia Company, the most important of these associations, then owned the gas supply from 54,000 acres of land situated on all the anticlinals around Pittsburgh, but drew its supplies only from Tarentum and the Murraysville field. It supplied, in 1886, 470 factories and about 5,000 dwellings within the city, besides many factories and dwellings in Alleghany and in numerous neighbouring villages. The average gas-pressure at the wells, when the escape is shut off, is about 500 lb. per square inch, and in the case of new wells this pressure is very greatly exceeded. In order to minimise the danger from leakage, the gas-pressure in the city is reduced to a maximum of 13 lb., and is regulated by valves at a number of stations under the control of a central station. The usual pressure in the larger lines is from 6 to 8 lb., while in the low-pressure lines it does not exceed 4 to 5 ounces.

The effect of the change from coal gas to natural gas upon the atmosphere over Pittsburgh has been most marked: formerly the sky was constantly obscured by a canopy of dense smoke; now the air is clear, and even white paint may with impunity be employed for the house fronts.

The very rapid development of the employment of natural gas is not confined to the neighbourhood of Pittsburgh; it is used for heating purposes in the cities of Buffalo, Erie, Jamestown, Warren, Olean, Bradford, Oil City, Titusville, Meadville, Youngstown, and perhaps twenty more towns and villages in Pennsylvania and North-western New York. In North-western Ohio, the cities of Toledo and Sandusky, the towns of Findlay, Lima, Tiffin, Fostoria, and others in that section are also supplied with natural gas; a pipe line has moreover been recently laid to Detroit, Mich., and it is estimated that in these localities 36,131,669,000 cubic feet of the gas were consumed during last year, superseding 1,802,500 tons of coal. To the south-west of Pittsburgh there are many smaller places which consume natural gas; it also occurs in considerable quantity, and is being utilised, in Indiana (whence an account has recently reached us of a terrific subterranean explosion of the gas); and it is at the present time contemplated to carry a natural gas-supply to Chicago.

The utilisation of the natural gas of the Russian oil-fields, although of very ancient date, has hitherto not been extensive, neither does the magnitude of the supply appear to bear comparison with that of the Pennsylvanian district.

A form of gaseous fuel which has long been known to technical chemists and metallurgists, but which has of late attracted considerable attention, especially in connection with the recent interesting work relating to its applications pursued by Mr. Samson Fox, of Leeds, has become, within the last four years, a competitor, in the United States, both of the natural gas of Pennsylvania and of coal-gas. Since Felix Fontana first produced so-called water gas in 1780, by passing vapour of water over highly-heated fuel, many methods, differing chiefly in small details, have been proposed for carrying out the operation, with a view to the ready and cheap production of the resulting mixture of hydrogen and carbonic oxide, and numerous technical applications of water-gas have been suggested from time to time, with no very important results, excepting as regards its use for lighting-purposes. Being of itself non-luminous, its utilisation in this direction is accomplished, either by mixing it with a highly luminous gas, or by causing a hydrocarbon vapour to be diffused through it; or the non-luminous flame, produced by burning it in the air, is made to raise to incandescence some suitably prepared solid substance, such as magnesia, lime, a zirconium salt, or platinum, whereby bright light is emitted. The objection to its employment as an illuminant for use in buildings, to which great weight is attached by us, and rightly, as sad experience has shown—viz., that, as it consists, to the extent of about one-half its volume, of the highly poisonous gas carbonic oxide, the atmosphere in a confined space may be rendered irrespirable by a small accidental contamination with water-gas, by leakage or otherwise, not detectable by any odour—appears to constitute no great impediment to its employment in the United States, as it is now manufactured for illuminating and heating purposes by a large proportion of their gas-works, being in some places employed in admixture with a highly luminous coal-gas, in others rendered luminous by the alternative methods mentioned. It is stated that about three-fourths of the illuminating gas now supplied to the cities of New York, Brooklyn, Philadelphia, Jersey, St. Paul, and Minneapolis, is carburetted water-gas; in Chicago the entire supply now consists of this gas, and Boston will also soon be supplied exclusively with it. The use of water-gas for metallurgic work does not appear to be contemplated in the United States, but it is especially to such applications of the gas that much attention has been devoted here in Leeds; and although some eminent experts are sceptical regarding the attainment of advantages, especially from an economical point of view, by the employment of this form of gaseous fuel, especially after practical experience in the same direction acquired in Germany, the technical world must feel grateful to Mr. Fox for his work in this direction, affording, as it does, an interesting illustration of the qualities of perseverance and energy which, when combined with sound knowledge, often achieve success in directions that have long appeared most unpromising; qualities which have been characteristic of many pioneers in industrial progress in this country.

Leeds has been especially fortunate in the possession of such pioneers, who, when competition brought about great changes in the particular trade through which, for many generations, this city chiefly enjoyed prosperity and high renown, developed its power and resources in new directions, from which success soon flowed in continually increasing measure. The rapid rise of Leeds to its present high position in industrial prosperity and national importance most probably dates from the period when its chief staple industry began to experience serious rivalry, in its own peculiar achievements, on the part of other districts of the kingdom and of other countries. From early days a flourishing Centre of one of the provinces of Great Britain most richly endowed with some of Nature's best treasures, Leeds could scarcely have failed, through the energy, acute intelligence, and powerful self-reliance especially characteristic of the men of Yorkshire, to rapidly acquire fresh renown in connection with industries which either were new to the town and district, or had been pursued in comparatively modest fashion, and which have combined to place the Leeds of to-day upon a higher pinnacle of commercial prosperity, power, and influence than her patriotic citizens of old could ever have dreamt of.

An examination into the present educational resources of Leeds places beyond any doubt the fact that her present prosperity in commerce and industries is in no small degree ascribable to the paramount importance long since attached here to the liberal provision of facilities for the diffusion of knowledge among the artisan and industrial classes, and especially for the acquisition of a sound acquaintance with the principles of the sciences and their applications to technical purposes, with particular reference to the prominent local industries, by all grades of those who pursue or intend to pursue them. There is, probably, no town in the kingdom more amply provided with efficient elementary and advanced schools for both sexes, while the special requirements of the artisan are efficiently met by the prosperous School of Science and Technology. The resources of the Yorkshire College provide, in addition, a combination of thorough scientific education with really practical training in the more important local industries; indeed, during the sixteen years of its continually-progressive work, this institution has acquired so widespread a reputation that students come from abroad to reap the advantages afforded by the unrivalled textile and dyeing departments of the Leeds College. The keen competition now existing between these departments and the corresponding branches of the much younger but most vigorous sister College at Bradford, can only conduce to the further development of both, and to their thorough maintenance up to the requirements of the day.

The very important pecuniary aid afforded to these establishments, and to a number of other technical schools in Yorkshire, by one of the most important of the ancient companies of the City of London, the Clothworkers, affords an interesting illustration of the good work in the cause of education performed by those Guilds and, especially of late years, by means of their flourishing Institute for the advancement of technical education, which, through its two great instructional establishments in London, and through the operation of its system of examinations throughout the country, extending now even to the Colonies, has afforded very important aid towards eradicating the one great blot upon our national educational organisation. To have been first in the field in practically developing a far-reaching scheme for the advancement of technical education in this country must continue to be a source of pride to the City of London and its ancient Guilds in time to come, when the operation of efficient legislation, supported and extended by patriotic munificence and by the hearty co-operation of associations of earnest and competent workers in the cause, shall have placed the machinery and resources for the technical instruction of the people upon a footing commensurate with our position among Nations.

The remarkable Address delivered by Owen here in 1858, wherein the condition, at that time, of those branches of natural science which he had made particularly his own was most comprehensively reviewed, included some especially interesting observations on the importance to the cultivation and progress of the natural sciences, and to the advancement of education of the masses in this country, of providing adequate space and resources for the proper development of our National Museum of Natural History; and it cannot but be a source of great satisfaction and pride to him to have lived to witness the thoroughly successful realisation of the objects of his own indefatigable strivings and powerful advocacy in that direction. Comprehensive as were the views adopted by Owen regarding the scope and possible extension of that museum, it may, however, be doubted whether they ever embraced so extensive a field as was presented for our contemplation by his successor last year, when he told us that a natural history museum should, in its widest and truest sense, represent, so far as they can be illustrated by museum-specimens, *all* the sciences which deal with natural phenomena, and that the difficulties of fitly illustrating them have probably alone excluded such subjects as astronomy, physics, chemistry, and physiology, from occupying departments in our National Museum of Natural History.

The application, in its broadest signification, of the title, Natural History Museum, may doubtless be considered to include, not only illustrations and examples of the marvellous works of the Creator and of the results of man's labours in tracing their intimate history and their relations to each other, but also illustrations of the means employed, and of the results attained, by man in his strivings to fathom and unravel the laws by which the domains of Nature are governed. But the reason why representative collections, illustrative of the physical sciences, do not form part of our National Natural History Museum, has, I venture to think, scarcely been correctly ascribable to any difficulty of organising fit illustrations of methods of investigation, of the attendant appliances, and of the results attained by experimental research; it appears rather, to exist in the fact that physical science has hitherto had no share in such a combination of circumstances as has been favourable to the good fortunes and advancement of the natural sciences, and as is analogous to those which, from time to time, give rise to the provision of increased accommodation for our National Art Treasures. Our present National Science Collection, which has, indeed, had a struggle for existence, does not owe the development it has hitherto experienced to any such moral pressure as has been several times exercised in the case of our art collections, by the munificence of individuals, with the result of securing substantial aid from national resources; its gradual increase in importance has been due to the untiring perseverance of men of science, and of a few prominent influential and public-spirited authorities, in keeping before the public the lessons taught by careful inquiries, such as those entrusted to the Royal Commission on Scientific Instruction, into the opportunities afforded for the cultivation of science and the development of its applications, in other Countries, as compared with those provided here.

The success of the efforts made in 1875 by a committee thoroughly representative of every branch of experimental science, to bring together in London an international loan collection of scientific apparatus, and the widespread interest excited by that collection, led the President of the Royal Society, in union with many distinguished representatives of science, to lay before our Department of Education a proposal to establish a national museum of pure and applied science, including the Museum of Inventions, which had already existed since 1860 as a nucleus of a science-museum, the establishment whereof had formed part of the original scheme of the Science and Art Department. The Loan Collection of 1876 did, in fact, and in consequence of the urgent representations then made, first put into practical shape the long-cherished desire of men of science to see an Institution arise in England similar to the Conservatoire des Arts et Métiers of France, and it became the starting-point of the National Collection, representative of the several branches of experimental science, which has been undergoing slow but steady development since that time, patiently awaiting the provision of a suitable home for its contents. This collection, which illustrates not only the means whereby the triumphs of experimental research have been and are achieved, but also the methods by which these departments of science are taught, yields, small as it is, to none of our national museum treasures in interest and importance.

In yet another way did that Loan Collection become illustrious: one of the most interesting features connected with it was the organisation of a series of important conferences and explanatory lectures, serving to illustrate, and also greatly to enhance, its value, and affording the best exemplification of the way in which such collections must exercise direct influence upon the advancement of science and upon the diffusion of scientific knowledge. These lectures and conferences demonstrated the wisdom of the suggestion made by the illustrious representative of associated Science in Leeds eighteen years previously, that public access to museums should be combined with the delivery of lectures emphasising and amplifying the information afforded by their contents. The example then set of thoroughly utilising for instructional purposes, and for the advancement of science, a collection illustrative of the physical sciences, has since been followed by the Science and Art Department; illustrative lectures connected with the existing nucleus of a national science-collection have been delivered from time to time, and the objects in the collection are constantly utilised in the courses of instruction at the adjoining Normal School of Science.

Although the national importance of thoroughly representative and continuously-maintained science collections has long been manifest, not only to all workers in science, but also to all who have cared to inquire, even superficially, into the influence of the cultivation of science upon the industrial and commercial prosperity of the country, the labours of a Royal Commission, and of successive Committees, in demonstrating the necessity for the provision of adequate accommodation for such collections, and for their support upon the basis of that afforded to the natural history collections, have been very long in bearing fruit. However, lovers of science, and those who have the prosperity of the country near at heart, have at length cause for rejoicing at the acquisition by the Nation of a site in all respects suitable and adequate for the accommodation of the science collections, which, as soon as appropriate buildings are provided for their reception, will not fail, in comprehensiveness and completeness, to become worthy of a Country which has been the birthplace of many of the most important discoveries in science, and of a People who have led the van among all Nations in making the achievements of science subservient to the advancement of industries and commerce.

The site selected as the permanent home of our National Science Collections is immediately in rear of the Natural History Museum, and faces the stately edifice, now rapidly progressing towards completion, for the erection of which, as an Imperial memorial of the Queen's Jubilee, funds were provided by voluntary contributions from every portion of the Empire and every class in the Empire's Nations. The Imperial Institute, the conception of which we owe to His Royal Highness the Prince of Wales, occupies a central position among buildings devoted to the illustration and cultivation of pure and applied Science and of the Arts—*i.e.* the Normal School of Science, the Technical College of the City and Guilds of London, the National Schools of Art, the Science Museum, the South Kensington Museum, and the Royal College of Music; to which list we may ere long see added a National Gallery of representative British Art. A more fitting location could scarcely be conceived for this pre-eminently National Institution, which has for its main objects the comprehensive and continuously progressive illustration—of the practical applications of the vast resources presented by the Animal, Vegetable, and Mineral Kingdoms to Industries and the Arts; of the extent, and the progressive opening up, of those resources in all parts of the Empire; of the practical achievements emanating from the results of scientific research; and of the utilisation of the Arts for the purposes of daily life. With the attainment of these objects it will be the function of the Imperial Institute to combine the continuous elaboration of systematic measures tending to stimulate progress in trades and handicrafts, and to foster a spirit of emulation among the artisan and industrial classes. Another branch of the Institute's work, upon which it is already engaged, is the systematic collection of data relating to the natural history, commercial geography, and resources of every part of the Empire, for wide dissemination together with all current information, bearing upon the commerce and industries of the Empire and of other Countries, which can be comprised under the head of Commercial Intelligence. The achievement of these objects should obviously tend to maintain intimate intercourse, relationship, and co-operation between the great Home and Colonial centres of Commerce, Industries, and Education, and to enhance importantly our power of competing successfully in the great struggle, in which Nations are continuously engaged, for supremacy in commercial and industrial enterprise and prosperity.

To the elaboration of the practical details of a system of operation calculated to secure the objects I have indicated, eminent public-spirited men are now devoting their best energies, with the sanguine expectation of realising the hope cherished by the Royal Founder of the Imperial Institute, that this memorial of the completion, by our beloved Sovereign, of fifty years of a wise and prosperous reign, is destined to be one of the most important bulwarks of this Country, its Colonies and Dependencies, by becoming a great centre of operations, ceaselessly active in fostering the unity, and developing the resources, and thus maintaining and increasing the power and prosperity, of our Empire.

REPORTS

ON THE

STATE OF SCIENCE.

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Report of the Corresponding Societies Committee, consisting of Mr. FRANCIS GALTON (*Chairman*), Professor A. W. WILLIAMSON, Sir DOUGLAS GALTON, Professor BOYD DAWKINS, Sir RAWSON RAWSON, Dr. J. G. GARSON, Dr. JOHN EVANS, Mr. J. HOPKINSON, Professor R. MELDOLA (*Secretary*), Professor T. G. BONNEY, Mr. W. WHITAKER, Mr. G. J. SYMONS, General PITT-RIVERS, *and* Mr. W. TOPLEY.

THE Corresponding Societies Committee of the British Association beg to report to the General Committee that the two meetings of the Conference of Delegates were held on Thursday, September 12, and Tuesday, September 17, 1889, at 3 P.M., in the Committee Room of Section C, at Newcastle-upon-Tyne.

The following Delegates were nominated for the Newcastle Meeting:—

Rev. H. H. Winwood, M.A., F.G.S.	Bath Natural History and Antiquarian Field Club.
Mr. William Gray, M.R.I.A.	Belfast Naturalists' Field Club.
Mr. John Brown	Belfast Natural History and Philosophical Society.
Mr. Charles Pumphrey	Birmingham Natural History and Microscopical Society.
Prof. B. C. A. Windle, M.D.	Birmingham Philosophical Society.
Mr. Alfred E. Hudd, F.S.A.	Bristol Museum and Library.
Mr. Peter Price	Cardiff Naturalists' Society.
Mr. W. P. J. Fawcus, C.E.	Chester Society of Natural Science.
Mr. W. F. Howard, Assoc.M.Inst. C.E.	Chesterfield and Midland Counties Institution of Engineers.
Mr. Thomas Cushing, F.R.A.S.	Croydon Microscopical and Natural History Club.
Mr. J. Goodchild, F.G.S.	Cumberland and Westmorland Association for the Advancement of Literature and Science.
Mr. A. S. Reid, M.A., F.G.S.	East Kent Natural History Society.
Mr. Robert Brown, R.N.	East of Scotland Union of Naturalists' Societies.
Mr. William White, F.E.S.	Essex Field Club.
Mr. D. Corse Glen, F.G.S.	Geological Society of Glasgow.
Prof. F. O. Bower, M.A., D.Sc.	Natural History Society of Glasgow.

Mr. W. C. Crawford, M.A.	Philosophical Society of Glasgow.
Rev. A. G. Joyce	Hampshire Field Club.
Dr. John Evans, Treas.R.S.	Hertfordshire Natural History Society and Field Club.
His Honour Deemster Gill	Isle of Man Natural History and Antiquarian Society.
Mr. S. A. Adamson, F.G.S.	Leeds Geological Association.
Mr. G. H. Morton, F.G.S.	Liverpool Geological Society.
Mr. I. C. Thompson, F.L.S.	Liverpool Microscopical Society.
Mr. M. B. Slater, F.L.S.	Malton Field Naturalists' and Scientific Society.
Mr. Eli Sowerbutts	Manchester Geographical Society.
Mr. Mark Stirrup, F.G.S.	Manchester Geological Society.
Prof. G. A. Lebour, M.A., F.G.S.	North of England Institute of Mining and Mechanical Engineers.
Dr. J. T. Arlidge, A.M.	North Staffordshire Naturalists' Field Club.
Mr. C. A. Markham, F.R.Met.Soc.	Northamptonshire Natural History Society.
Mr. Robert Brown, R.N.	Perthshire Society of Natural Science.
Mr. H. R. Mill, D.Sc.	Royal Scottish Geographical Society.
Mr. W. Andrews	Warwickshire Naturalists' and Archæologists' Field Club.
Rev. J. O. Bevan, M.A.	Woolhope Naturalists' Field Club.
Mr. J. W. Davis, F.G.S.	Yorkshire Geological and Polytechnic Society.
Rev. E. P. Knubley, M.A.	Yorkshire Naturalists' Union.

By the sanction of the Council, the Lisbon Geographical Society was represented by Professor Batalha-Reis.

At the first Conference the chair was taken by Mr. Francis Galton, the Corresponding Societies Committee being also represented by Dr. John Evans, Mr. W. Whitaker, and Mr. W. Topley.

The Chairman proposed that the Report of the Corresponding Societies Committee to the General Committee, printed copies of which had been distributed among the Delegates, should be taken as read in order to save time. The proposal was put to the meeting and carried. The Chairman then invited the Delegates to make any statements respecting the work done by Committees appointed last year, or in connection with other subjects referred to in the Report. He suggested that the various Sections should be taken in alphabetical order.

No statements were made respecting Sections A and B.

SECTION C.

Erratic Boulders, &c.—The Rev. E. P. Knubley called attention to the fact that the Yorkshire Naturalists' Union, working in harmony with the British Association, were endeavouring to form a Boulder Committee. They had done very good work for about three years, and they had this year submitted a number of reports to the British Association Committee, all of which had been accepted. They had also added a Yorkshire Fossil Flora Committee, which was working on the same lines as that proposed by the British Association. No report had been presented as yet, but a great deal of matter had been collected, and an interim report was to be presented in November, when the Yorkshire Naturalists' Union held their annual meeting. They had also appointed a Coast-Erosion Committee, which was working in connection with the British Association, and a

Marine Zoological Committee, which had had one dredging excursion this year.

Geological Photography.—Mr. Knubley next referred to the subject of geological photography, which had been brought forward in 1888. It was then felt that the proposal was too vague to bring in any definite form before the different Societies, but the matter had become more definite in the course of the year, and he thought that the time had arrived for proposing that a Committee should be formed to arrange the collection of photographic views illustrating the geological features of each county of the United Kingdom.

A discussion ensued as to the mode of procedure to be adopted in order to give practical effect to the conclusions already arrived at by those members of the Corresponding Societies who had been working at the subject during the year.

Mr. O. W. Jeffs, having been called upon by the Chairman, stated that the matter had been brought before the Delegates at Bath in 1888, and had been discussed on that occasion. The proposal had then been left in an informal condition, and he undertook to communicate with the Delegates of the different geological societies of the kingdom. He had done this in an unofficial and private circular, and now had a list of what each had obtained, as well as a large collection of photographs, some of which were very interesting. He added that he had received letters from a large number of Delegates highly approving of the scheme, and offering suggestions. These letters would be placed at the disposal of Section C or of anyone taking the matter up.

No formal recommendation with respect to the subject was passed at the Conference, as the matter was to be brought before the Committee of Section C the following day.

Earth Tremors.—Professor Lebour said he had very little to say on this subject except that the work in his district had been suspended as the result of the recommendation of the Earth Tremor Committee of the British Association, which considered that the spot selected for the instruments was too near the sea, and rocks containing great cavities, and therefore unsuitable for the experiments. A good deal of time had been taken up last year in having a new set of instruments made and placed in another position. They were now ready for work, but no observations had been taken owing to the change of position.

The Geological Record.—Mr. Topley called attention to a circular which had been distributed among the Delegates, in which it was pointed out that the publication of this Record of geological literature could not be continued unless the number of subscribers was increased, and he urged upon those present to assist the cause of science by giving their own and getting others to give their support. Mr. Whitaker also spoke on behalf of the Record.

No subjects coming within the province of Sections D, E, F, or G were brought forward.

Section H.

Catalogues of Ancient Remains.—Mr. William Gray said that a Committee of the British Association had been appointed for this purpose, and the Society which he represented had made a commencement in

Ireland, taking the two counties Antrim and Down. They had prepared a list and maps, plotting on the latter the sites of monuments and ancient settlements in accordance with the regulation code of signals adopted by the International Congress on Archæology some years ago. He had the maps with him, but had not been able to send the communication to the Secretary of the Committee (Mr. J. W. Davis) in time for that year's Report. The list as at present prepared was simply a catalogue in which it had not been thought desirable to give any great amount of detail beyond references to such authorities as could furnish further information. The list was to be regarded simply as tentative, and he now submitted it to the Conference in order to see whether a right start had been made, and whether any amendments could be suggested. The one-inch Ordnance sheets had been used as a basis, and these had been plotted in accordance with the scheme referred to, but they had also tried to avoid a difficulty (generally met with in catalogues of this kind), and that was the difficulty of indicating to a stranger the exact position of any given object. They had adopted a method which he hoped would meet with the approval of the Conference. Instead of stating the latitude and longitude, or the relative position from any stated town, they had adopted the simple plan of stating the sheet on which the object occurred and its distance in inches from north and west on that sheet. Thus if a certain place A was said to be six miles from B, no one would get much idea of the position, but if it was recorded that the place was on sheet 26, six inches from the top (north) and eight inches from the west, the exact position of the monument could be at once entered on any other copy of the map, and then the catalogue reference would give details of any published information concerning that monument.

Mr. Gray then exhibited one of the maps (Antrim), and explained that, instead of making the signs in the same way as that adopted by the International Congress, which rendered them somewhat indistinct, he had punched out small pieces of red paper and gummed these on to the map. In addition to this a concise tabular form had been prepared giving much information on the subject, a list of the ancient settlements or sites and the monuments found, their characters and relative numbers, &c. A list of the standing stones had also been commenced, this list containing some of the more important ones, and it was hoped to complete it by degrees so as to comprise all. There was also a list of stone circles, tumuli, and other sepulchral monuments, castles and stone forts of Ireland, caves, artificial and natural, &c.

Dr. John Evans said that the Delegates might like to know that the Society of Antiquaries had undertaken an archæological survey of England. The principle on which that survey was being carried on was in the main that adopted by Mr. Gray, but for ordinary publication maps could not be employed on so large a scale. They entered not only the prehistoric, but the Roman and Saxon remains and earthworks. Each county would be accompanied by a list which would be classified under different heads and indexed, so as to show the discoveries which had been made. It seemed to the Society of Antiquaries that a survey of this sort would be of great use throughout the kingdom, and they were appealing to the members of different archæological societies to assist in carrying it out. Some of the Societies represented, in addition to looking after the natural history of their districts, were also concerned with their antiquities. A congress of Delegates had been held in the rooms of the

Society of Antiquaries, and it was hoped that this would become an annual gathering. They did not intend to compete with the Corresponding Societies Meeting in this matter; they rather looked upon the Societies meeting here as representing the biological side of all the questions brought forward, whereas the Society of Antiquaries represented the purely archæological side. The survey of Kent had been published, others were in hand. The scale was only eight miles to the inch, but that scale would be found of sufficient size to note all the discoveries, and by means of the index he thought it would prove a most useful addition to the archæological publications of the country.

In concluding the business of the first meeting the Chairman expressed their indebtedness to Professor Meldola, who had acted as Secretary to the Corresponding Societies Committee throughout the year, and to Professor Lebour, who had consented to act as Secretary to the present Conference.

At the second Conference the chair was taken by Mr. Wm. Topley, F.R.S., the Corresponding Societies Committee being also represented by Dr. Garson. The Secretary having read the minutes of the first Conference, the Chairman suggested that it would be convenient to follow the usual course, and before going to miscellaneous business to take up the suggestions and recommendations from the various Sections.

Section A.

Temperature Variation in Lakes, Rivers, and Estuaries.—Dr. Mill stated that the report of the Committee appointed last year had been adopted by Section A with a recommendation for its reappointment with a grant. The object of the Committee was to accumulate as great a number of data with regard to the temperature of the surface of lakes, rivers, and estuaries, and the sea near the shore, as could possibly be obtained, in order to discuss these in connection with the meteorology of the country. It was a problem of some difficulty, and the object sought to be obtained in bringing it before the Corresponding Societies was to spread the work over a very wide tract of country, so as to get such diverse conditions as it was impossible to obtain by a few isolated workers. As a result of the circulars sent to the Corresponding Societies last year, they had obtained twenty-four sets of observations on the rivers and some estuaries in England, twenty-one in Scotland, eleven in Ireland, and one in the Isle of Man. He did not think it necessary to read the names of the rivers, but he would merely say that he would be very pleased if the Delegates present, representing Societies which had not yet seen their way to take up this work, should, on their return, be able to find out some members able and willing to make these daily observations on exposed water in their own neighbourhood. He would be very pleased if they would communicate with him, or any other member of the Committee, and instructions would be immediately sent for setting the observations going. He had a report recently from the Manchester Geological Society showing the observations made there on the reservoirs of the Oldham Waterworks—observations of great interest, and evidently, from the record published in the Transactions of the Manchester Geological Society, carried out with great detail and in a thoroughly satisfactory and trustworthy manner. The success of the research depended entirely on the extent and fulness with which the different observers carried out their work.

Mr. John Brown said he had brought the matter before the Belfast Natural History and Philosophical Society. Professor Everett, one of the members, was strongly of opinion that it was not the business of the local Societies, but should rather be given to the observers of rainfall, who were accustomed to making observations of a similar kind, and to a certain extent were better organised for getting the information than their own Society.

Mr. A. S. Reid said the East Kent Natural History Society had taken this matter up since the last meeting, and were now carrying it on, having two observers on the river Stour. They had not yet published an actual report in their Transactions, but simply an interim report; a fuller report was being prepared. The Committee was doing work, and he believed good work, and was certainly taking a great deal of interest in the matter, and it had been the means of giving the local Societies something to do, and also of helping them to affiliate with other Societies round them. He expressed the opinion that the indication of lines of useful investigation of this kind had done a great deal of good in bringing together the Societies in his district.

Dr. Mill, in answer to the remarks made, said that this work which had been taken up by the Committee, and in which the help of the Corresponding Societies was wanted, did not in the least degree clash with any other organisation or the carrying on of any other work. If all the meteorological observers were willing and able to carry on additional experiments, it would add a very great deal to the fulness and completeness of their meteorological reports; but, in point of fact, those observers had their hands sufficiently full as a rule in taking their daily observations, and might not care to add to their work. Professor Fitzgerald, however, had taken the matter up in Ireland and had obtained the services of a number of observers, many of whom were rain-gauge observers—in fact, he thought almost all.

No communication with respect to Section B was brought forward.

SECTION C.

The Chairman announced that Mr. De Rance had been nominated by the Committee of Section C to represent that Section at the Conference.

Mr. De Rance said that the Committees in which Section C was more particularly interested, and in which the Corresponding Societies could be—and, indeed, were—of great value were—

The Underground Waters Committee, of which he happened to be Secretary. It was appointed some fifteen years ago in the town of Belfast to inquire into the water of the New Red Sandstone and Permian formations as concerned with the water supply of the town and district. At subsequent meetings of the Association the scope of its inquiry had been enlarged until at the present time it comprised the whole of the porous or permeable formations of this country. The Committee of the British Association which had been doing this work had done it by means of forms of inquiry as to the nature of the sections passed through in wells and borings for water, the effect of faults upon the water-supply, the character and quality of the water obtained, and the varying heights at which the water was found to stand, when the works were first commenced and after long pumping. The questions were drawn up with considerable care, and had been added to from time to time, and he thought they now practically grasped the whole subject. The Secretary of the Committee would have great pleasure in giving either a number of these forms, or a sample copy, to any Secretary of the Corresponding Societies throughout the country who might be desirous of being supplied with the same. The Committee in their present report (the fifteenth) laid before Section C comment on the fact that no less than three Societies have printed valuable information on this subject on the lines which had been adopted by the Committee of the British Association, and the more important of their sections and details had been printed in this fifteenth report.

Then there was the Committee of Inquiry into the position and character of—

Erratic Boulders. Dr. Crosskey, its indefatigable Secretary, intended in the future to get a series of maps on which the position of the more important boulders should be entered, and he (Mr. De Rance) believed it was intended to take the one-inch Ordnance maps and to place upon them the actual position of the boulders which had been recorded; as far as possible, the character and point of origin of those boulders are also being determined. Dr. Crosskey had presented his last report—the seventeenth—before Section C, and he (Mr. De Rance) believed that already the bringing of this work before the Corresponding Societies had borne fruit. He had received, independently of the British Association, a circular from the Liverpool and some other area in which evidently an endeavour had been made to form a committee to go into the subject on the lines of the original inquiry which had been carried out with so much success by Dr. Crosskey, who, he knew, was most anxious to give to the Secretaries of the Societies represented by Delegates copies of the printed forms of inquiry as to the position of boulders, their nature and character, and to ascertain from them whether steps should be taken to preserve them as memorials of the past.

Another Committee was the—

Coast-Erosion Committee, which had been taken up by his colleague, Mr. Topley, who had drawn up all the valuable reports on coast erosion already published by the British Association. That Committee required the rate of erosion of the sea on the coast of this country, and inquired as to how far that regular erosion had been artificially increased by the operations of man, by the cutting away of stone upon the sea-cliffs for economic and building purposes, and by the building of sea-walls in positions and under conditions which were unadvisable, and by breakwaters not leading the water in the right way, which in many cases increased the coast erosion. Already much valuable information had been put together by Mr. Topley in the reports which had been published; but these only covered a portion of the country, and erosion was gradually and steadily going on all round the coast. The Corresponding Societies which happened to be on the seaboard had great facilities for studying this question: first, in seeing the actual rate of erosion going on at the present time, and, secondly, in regard to looking up old plans, documents, and deeds, which might show the position of the land in times gone by.

Geological Photography.—Mr. De Rance said that all would admit the great importance of the subject. Mr. Jeffs had already recorded a number of photographs, and this was a suitable matter for the local societies, for there were many local circumstances to be dealt with, and the best mode of photographing, the best time, and so forth, could only be dealt with by people living on the spot. All the Delegates would feel that this was a subject they could represent to their Societies as one which should be carried out.

Mr. Gray said there were erratic blocks in Ireland, particularly in the north; he did not know whether these blocks had been recorded, but if such a catalogue would be of any assistance to Mr. De Rance he would be glad to undertake its preparation for Antrim, Down, and Derry.

Mr. Topley said there should certainly be a record of the boulders of Ireland, but he was afraid the present Committee only referred to the erratic blocks of England and Wales; it would, however, be very easy to extend it next year if Mr. Gray would forward the information to Dr. Crosskey, and if that gentleman were not prepared to take charge of it another Committee could be formed.

Mr. De Rance stated, with respect to the question of erratic blocks, that as Dr. Crosskey was not present, and as he had had some conversation with that gentleman on the question of including Ireland, he would venture to suggest that it was first of all exceedingly important and necessary that the boulders of Ireland should be recorded in the same manner as in England; secondly, as it was too late this year to include the Irish with the already existing English Committee, a Committee could easily be formed by Mr. Gray himself, or by others in Ireland who would undertake the inquiry. It should follow the lines, and the questions should be put in the same way as that adopted by the English Committee on Erratic Boulders. At the meeting at Leeds the Irish Committee could, he thought, be amalgamated with the English one; it would then be a general Boulder Committee, and the reports might be taken together or separately, and the facts collected during the year would make the first report.

Professor Lebour, referring to the subject of Geological Photography, said that, as Mr. De Rance had already mentioned, Section C, since the first Conference, had had this matter referred to them for consideration, and he might say there was the greatest possible unanimity when it was brought up. The subject was one which all geologists would agree was a most useful one. Mr. Jeffs, as a member of Section C, explained the system which he and Mr. Adamson had so far adopted; that method was regarded as no doubt a good one, but the whole question of detail was left to the Committee to report upon. He might say that it had been passed on to the Committee of Recommendations that same day. The members of the Committee were Professor Geikie (Chairman), Professor Bonney, Mr. A. S. Reid, Mr. S. A. Adamson, Professor Boyd Dawkins, Mr. W. Gray, and Mr. Jeffs as Secretary. He thought they would see that the Committee was chosen with some thought as representing different parts of the country, so that a considerable area would be covered, and the different features of the various districts would not be overlooked. The Committee was not only appointed to do the work of collecting, preserving, and registering in a systematic way the photographs of places of geological interest, geological sections, and so on, but he thought in the first instance it was chiefly for the purpose of seeing how the work could best be carried on in the future, and one of the most important points they would have to consider was where the photographs, when once obtained, were to be lodged and preserved in safety for consultation. That was left, however, to the Committee to report upon, but there was no reason why the Conference should not express its views as to what would be a good place. He thought the best thing would be to communicate to the Secretary of the Committee any suggestions the Conference might discuss.

Mr. Topley said he would like to say a few words about the Coast-Erosion Committee. The importance of local observation in this subject was much impressed on him lately when he paid a visit to Selsea. He was sure the loss of land at various places (comparing it with the large six-inch Ordnance Survey maps made, he thought, sixteen years before) was very large; he did not know the coast well previously, and could not tell the annual wear, nor whether it went on evenly. He spoke to Mr. Clement Reid about it, and he said it was lost during the years since the maps were made, but the average did not represent the annual loss, as of late the rate of erosion had been very rapid. It was impossible for any but local observers to record such an important fact as that. Local observers were wanted to take measurements from certain known positions—the corner of a house, a hedge, or any other fixed object—to make notes and compare them, and by such means to accurately record what was going on, and at the same time it would be seen whether the loss was greater at one place or at one time than at another. It would be a most desirable thing for local Societies to take up. The Yorkshire Naturalists Union, as Mr. Knubley told them at the last meeting, had already done so. He had hoped that the Isle of Man Society would also have taken it up; they had applied for forms, and perhaps Deemster Gill would see to the matter. From East Kent they had most valuable information from Mr. Dowker, a member of the East Kent Natural History Society.

Section D.

Mr. Knubley said that he had been asked to represent Section D and to bring before the Conference two matters:—

Disappearance of Native Plants.—They would remember that Professor Hillhouse came last year prepared with a report and found no Committee existing; that Committee was, however, revived, and during the course of the year it had apparently done a considerable amount of work. In this report, which he held in his hand, they treat of the disappearance, or partial disappearance, of fifty-five different kinds of plants in Scotland, their attention being confined entirely to Scotland for the present; they attribute most of the disappearances to the action of dealers and collectors; they would be very glad if local naturalists' societies would take the matter up and try to chronicle the disappearance of plants as far as they can. Professor Hillhouse suggests the use of the eighth edition of the 'London Catalogue' as a basis for their observations. He calls attention particularly to the disappearance of certain plants, and shows the way in which they might disappear—for instance, *Hypericum quadrangulum* disappeared, having been eaten by cattle or trodden down. In another case *Sedum reflexum* has disappeared from a wall owing to repairs. Various other ways are mentioned, and amongst these drainage seemed to have been a great cause of the disappearance of native plants.[1]

[1] See *Reports*, 1889, p. 435.

Investigation of the Invertebrate Fauna and Cryptogamic Flora of the British Isles.—The other matter he was commissioned to bring before the Conference was the Committee appointed that day for the above purpose. The Committee had Canon Norman for its chairman and Professor Ewart as secretary; three members for Ireland—Professor A. C. Haddon, Professor W. R. M'Nab, and Professor W. J. Sollas; three for England—Professor Lapworth, Mr. F. E. Beddard, and Dr. H. Scott; and three for Scotland—Professor Bayley Balfour, Professor J. C. Ewart, and Professor J. Geikie. The object of that Committee is to make a systematic investigation of the rivers and lakes, and it is hoped that the microscopists will undertake definite scientific work; they are exhorted, if they take up this investigation, to take note of the physical features of the stream or the lake which they study (of course including the geological features), and of the temperature at different periods of the year, and, in the case of lakes, at different depths, so that they would be working in conjunction with the Committee Dr. Mill referred to.

Local Museums.—Mr. John Brown said it was generally admitted that the casual visitor to local museums finds a want of interest in the latter through not knowing what to look at. Of course a scientific person wishing to look at a particular object goes to that department in which he is interested. It occurred to some of them in Belfast to give gratis a visitors' guide, pointing out objects of interest, so that they could see them at once without going through the whole museum. The idea was to make it as concise as possible, so as to draw attention to the objects of interest by putting them in heavy type, and therefore enabling the visitors to find out at once what was to be seen in each department. He had with him a few copies if any Delegate desired to see them.

Mr. Topley said there was a Committee of the British Association concerning local museums, but it had lapsed; it might be reappointed, and if so, it would be a very good thing to bring that matter before them as well. It was quite right to mention it at this Conference, but he thought there had been a Committee specially concerned with these matters.

Life Histories of Native Plants.—Mr. Knubley, in reply to the Chairman, said that he was not asked to say anything about this subject, but it seemed to him an admirable suggestion, and one which their Committee should take up.

Mr. Topley asked if anything with respect to Professor Balfour's valuable paper, submitted to the Conference last year, had been done in Section D. Mr. Knubley replied in the negative.

Mr. Gray said that he brought the matter before the Society he represented, and he knew that a friend of his, who was very well acquainted with the collection and cultivation of ferns, had undertaken a series of experiments outside his ordinary work with a view of endeavouring to promote Professor Balfour's objects.

Mr. Topley suggested that it would be well to bear the subject in mind and bring it before Section D next year.

SECTION E.

The Chairman said that he was not aware whether there was present any gentleman representing Section E, but they were in the interesting position this year of having a representative of a foreign Society, Professor

J. Batalha-Reis, as a Vice-President of that Section. By the sanction of the Council that gentleman represented at the Conference the Lisbon Geographical Society. If he had anything to tell them as to the way in which local Societies could do geographical work they would be glad to hear him.

The Geographical Society of Lisbon.—Professor Batalha-Reis said that, having been sent by the Geographical Society of Lisbon as a Delegate, he should be very glad if his presence on the present occasion led to some good scientific result. He saw the good work which local Societies were doing in England in connection with the British Association, and that led him to the belief that perhaps foreign Societies connected with the Association might do something useful if they could work systematically under a plan. He called attention to the capabilities of work of his Society and expressed the hope that the Geographical Society of Lisbon might perhaps help the work prosecuted by the British Association in some way. To begin with, the limits of geography as a science were rather vague, that is to say, geography was more or less in connection with all other sciences represented by the different Sections of the British Association. Thus the natural features of a district, its animals, minerals, and plants were strictly geographical, and at the same time had relationship with the biological, geological, and other sciences. Then, as they were aware, his country had in Africa, by the peculiar situation of their colonies, a large field where experiments and researches could be prosecuted. At that moment they had six expeditions working in Central Africa, and not only the leaders of those expeditions, but, he was pretty sure, all the naturalists connected with them, were members of the Geographical Society of Lisbon, most of them working under the instruction of that Society. Then, too, their colonies were in a very intimate connection with the English colonies in Africa, so that, if they could establish a joint plan of exploration, say from the Cape of Good Hope to the furthermost Portuguese settlement, valuable scientific results ought to be achieved.

No communications or recommendations from Section F were brought forward.

Section G.

Committee on Flameless Explosives.—Professor Lebour said the North of England Institute of Mining and Mechanical Engineers had one Committee which was mentioned last year (that on explosives) in full working order at the present time. When mentioned last year it was only about to be appointed; now it had begun its work, which was not simply that of examining the properties of all the so-called flameless explosives; the main object was a philanthropic one, so that an explosive which a dealer liked to call flameless, and which was not really flameless, might not be used unwarily by miners in positions where the use of an explosive carrying a flame under certain circumstances might be exceedingly dangerous. Now that they had a good deal more knowledge than formerly of such things as coal-dust explosions, it became very important indeed to avoid as far as could be any possibility of having a flame projected by a blown-out shot or any other currents of that kind in an atmosphere laden with particles of dust. It was a disputed question as to whether coal-dust itself was dangerous. If coal-dust did not cause an explosion itself it certainly conducted it. The explosion might be there before the coal-dust had anything to do with it, but if the coal-dust were present it carried the explosion farther than it would otherwise have gone, and changed what might be a harmless, or comparatively harmless, accident into sometimes a catastrophe of a very destructive character.

Committee on Fan-ventilation.—There was another Committee mentioned, he thought, last year—a joint Committee of three of the Mining Institutes of England—the Midland, South Wales, and North of England Institutes—appointed to carry out experiments on fans, especially with a view of observing the working where circumstances were such as to allow of two kinds of fans working in the same pit, and he had no doubt the result would be valuable to mining men. They must not forget that this Conference was one of the local scientific Societies, using the word in its wide sense, and not only of geological, natural history, and microscopic clubs, and he thought the report of this joint Committee would be of very great value to engineers connected with mines and with such other works as required artificial ventilation. As they had representatives from other engineering Societies he would like to say that the North of England Institute and the others he had mentioned as being jointly on the Committee would be exceedingly glad to receive any hints or any information which would tend to the carrying out in the best possible manner the objects referred to.

Mr. Howard, referring to the combination of the Mining Institutes which was about to take place, said that if this federation succeeded it might be a good hint to other local Societies to combine and have something in the way of joint publication. That was the principal thing the Mining Institutes were aiming at at present without at all destroying their individuality. He thought it was likely to prove successful, and whether it succeeded or not it was worthy the consideration of other Societies, concerned in different matters, to see whether they could not similarly combine, as it would be of great mutual advantage and economy.

SECTION H.

Committee of Aid.—Dr. Garson said he had to bring forward a matter of importance from Section H in which the local Societies could assist very materially. The Anthropological Institute during the preceding year had had under its consideration the fact that a large number of barrows and other antiquarian remains were year by year destroyed, not willingly but by injudicious exploration. They took into consideration whether there was any possibility of having the explorations of old barrows made on some definite plan, and for that purpose a Committee of Aid was formed, consisting of General Pitt-Rivers, Professor Flower (the President of the Association), Mr. Read (of the British Museum), Mr. Hilton Price, Mr. Lewis (Treasurer of the Anthropological Institute), and himself. This Committee was elected by the Council of the Anthropological Institute to draw up a series of directions for those who desire to explore barrows and other ancient remains. Special directions might be wanted in certain cases, and they would be extremely glad if anyone who was desirous of exploring a barrow would communicate with the Secretary of this Committee of Aid. The Committee was not formed for the purpose of exploring barrows, but to give advice to those who were about to undertake such exploration. They wished it distinctly understood that they did not want to interfere in any way with or to take the credit for any work undertaken. They only wished to have the work performed to the best advantage. It was not uncommon for a certain investigator, who was interested in pottery, to dig up one of those ancient structures and extract all the pottery. There might be other relics of great importance—there might be skulls or bones of various animals, all of which were important in fixing the date of the barrow or the habits of the people, and these things were all lost. In like manner people who were searching for human remains only were likely to overlook all the other things, such as works of art and other objects, which yield very valuable information. What they wanted made known as widely as possible was that the Committee was anxious to have communications sent to it and to know of all the work that was going on, and he thought they would see that that was a matter in which local Societies could materially assist. He had no doubt that if the explorations were carried on on a distinct system, such as that which the Committee would be able to suggest, very valuable results would be obtained where now a great deal of information was lost. He therefore commended this subject very specially to their attention. In local museums they had placed a printed card giving the address of the Secretary at the Anthropological Institute, 3 Hanover Square, London, where all communications regarding finds or explorations about to be made should be sent.

Prehistoric Remains Committee.—In reply to a question put by the Chairman, Dr. Garson said that this Committee, of which Mr. J. W. Davis was the Secretary, had through an oversight been allowed to lapse last year. They had, however, presented a very excellent report this year, and had applied for reappointment.[1]

At the conclusion of the scientific business a discussion took place respecting the placing of Delegates on the Sectional Committees. The following resolution was finally put to the meeting and carried:—

'That the relations of Delegates to the Sectional Committees as at present existing are unsatisfactory, and that the matter be referred to the Corresponding Societies Committee for their consideration.'

With reference to this resolution the Committee have to report that, after giving the matter careful consideration, they have come to the conclusion that they possess no power under the present rules of the Association of attaching Delegates to the Sectional Committees.

The Committee beg to recommend that the General Committee should sanction the retention of all the Corresponding Societies now enrolled, and that the Leeds Naturalists' Club and Scientific Association should be added to the list.

[1] The Committee, consisting of Sir John Lubbock (Chairman), Mr. J. W. Davis (Secretary), Dr. J. Evans, Professor Boyd Dawkins, Dr. R. Munro, Messrs. Pengelly and Hicks, Professor Meldola, and Dr. Muirhead, was appointed.

The Corresponding Societies of the British Association for 1889–90.

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Barnsley Naturalists' Society, 1867	Barnsley Nat. Soc.	Public Hall, Barnsley. Henry Wade, 10 Pitt Street	53	None	6*s.* and 10*s.* 6*d*	Transactions, occasionally.
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C.	Rev. H. H. Winwood, Royal Literary and Scientific Institution, Bath	88	5*s.*	10*s.*	Proceedings, annually.
Bedfordshire Archæological and Natural History Society, 1887	Beds. A. N. H. Soc.	F. A. Blaydes and F. B. W. Phillips, M.A., Harpur Place, Bedford	60	None	7*s.* 6*d.*	Transactions, occasionally.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	254	None	1*l.* 1*s.*	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C.	F. W. Lockwood, Waring Street, and R. Lloyd Praeger, B.E., Holywood, Belfast	251	None	5*s.*	Report and Proceedings, annually.
Birmingham Natural History and Microscopical Society, 1864	Birm. N. H. M. Soc.	W. H. Wilkinson and William P. Marshall, Mason College, Birmingham	202	None	1*l.* 1*s.*	'Midland Naturalist,' Monthly.
Birmingham Philosophical Society	Birm. Phil. Soc.	Prof. J. H. Poynting, 11 St. Augustine's Road, and C. Davison, 38 Charlotte Road, Birmingham	140	None	1*l.* 1*s.*	Proceedings, annually.
Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	University College, Bristol. Professor Adolph Leipner, 47 Hampton Park, Redland, Bristol	211, and 18 Associates	5*s.*	10*s.*	Proceedings, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	46 High Street. G. Harris Morris, Ph.D., F.I.C., 121 Alexandra Road, Burton-on-Trent	189	None	5*s.*	Annual Report. Transactions occasionally.
Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	R. W. Atkinson, B.Sc., F.I.C., 44 Loudoun Square, Cardiff	400	None	10*s.*	Report and Transactions, half-yearly
Chester Society of Natural Science, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum, Chester. G. R. Griffith and W. H. Okell	575	None	5*s.*	Annual Report. Transactions every three or four years.
Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. W. F. Howard, 13 Cavendish Street, Chesterfield	265	1*l.* 1*s.*	Members 31*s.* 6*d.*; Subscribers 21*s.*; Associates and Students 20*s.*	Transactions, quarterly.
Cornwall, Mining Association and Institute of, 1884	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	345	None	Minimum, 10*s.* 6*d.*	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	G. B. Millett, Penzance	100, and 16 Associates	None	1*l.* 1*s.*	Report and Transactions, annually.
Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C.	Public Hall, Croydon. F. C. Bayard, Manor Road, Wallington	297	None	10*s.*	Proceedings and Transactions, annually.
Cumberland and Westmorland Association for the Advancement of Literature and Science, 1876	Cumb. West. Assoc.	J. B. Bailey, 28 Eaglesfield Street, Maryport	926	None	5*s.*	Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	M. G. Stuart, New University Club, St. James's Street, London, S.W.	250	None	10*s.*	Proceedings, annually.

Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	Dumfries. Dr. E. J. Chinnock, Grey Friars, Dumfries	189	2*s.* 6*d.*	5*s.*	Transactions and Journal of Proceedings, annually.
East Kent Natural History Society, 1857	E. Kent N. H. Soc.	W. E. Drake, Victoria Road, Canterbury	63	None	Ladies, 5*s.*; Gentlemen, 10*s.*	Transactions, occasionally.
East of Scotland Union of Naturalists' Societies, 1884	E. Scot. Union	William D. Sang, 12 Townsend Crescent, Kirkcaldy, N.B.	10 Societies, 863 Membs.	None	Assessment of 4*d.* per member	Proceedings, annually.
Edinburgh Geological Society, 1834	Edinb. Geol. Soc.	H. M. Cadell, 5 St. Andrew Square, Edinburgh	233	10*s.* 6*d.*	12*s.* 6*d.*	Transactions, annually.
Essex Field Club, 1880	Essex F. C.	William Cole, 7 Knighton Villas, Buckhurst Hill, Essex	450	10*s.* 6*d.*	10*s.* 6*d.*	'Essex Naturalist,' quarterly.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. B. Murdoch, Capelrig, Mearns, Glasgow	200	None	10*s.*	Transactions, generally annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	D. A. Boyd and J. Steel, 207 Bath Street, Glasgow	367	7*s.* 6*d.*	7*s.* 6*d.*	Proceedings and Transactions, annually.
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc.	John Mayer, 207 Bath Street, Glasgow	660	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually; occasional papers.
Hampshire Field Club, 1885	Hants. F. C.	Hartley Institution, Southampton. W. Dale	212	None	5*s.*	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Herts N. H. Soc.	Dr. J. Morrison, F.G.S., Victoria Street, St. Albans	258	10*s.*	10*s.*	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C.	A. J. Crosfield, Carr End, Reigate	73	10*s.*	10*s.*	Proceedings, usually every two years.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	Thomas Wallace, High School, Inverness	184	None	5*s.*	Transactions, occasionally.
Ireland, Royal Geological Society of, 1831	R. Geol. Soc. Ireland	Prof. W. J. Sollas, F.R.S., Trinity College, Dublin	140	None	1*l.* 1*s.*	Journal, generally annually.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland	J. Pim, B.L., 35 Molesworth Street, Dublin	150	None	1*l.*	Journal, annually.
Leeds Geological Association, 1874	Leeds Geol. Assoc.	Wm. Lower Carter, F.G.S., 6 Oakfield, Headingley, Leeds	138	None	5*s.*	Transactions, annually.
Leeds Naturalists' Club and Scientific Association, 1878	Leeds Nat. C. Sci. Assoc.	80 Municipal Buildings, Victoria Square, Leeds. Arthur Walker	251	6*s.*	6*s.*	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	C. J. Billson, M.A., St. John's Lodge, Clarendon Park Road, Leicester	333	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Transactions, quarterly.
Liverpool Engineering Society, 1875	Liv'pool E. Soc.	Royal Institution. J. H. T. Turner, 3 Cook Street, Liverpool	201	None	1*l.* 1*s.*	Transactions, annually.
Liverpool Geological Society, 1858	Liv'pool Geol. Soc.	Royal Institution. W. Hewitt, B.Sc.	54	None	1*l.* 1*s.*	Proceedings, annually.
Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit. Phil. Soc.	Royal Institution. John Rutherford, LL.B., Wason Chambers, 4 Harrington Street, Liverpool	271	10*s.* 6*d.*	1*l.* 1*s.*	Proceedings, annually.
Liverpool Microscopical Society, 1868	Liv'pool Mic. Soc.	Royal Institution. Wm. Oelrichs, Sunnyside, Wexford Road, Oxton	133	10*s.* 6*d.*	10*s.* 6*d.*	Report, annually; Transactions, occasionally
Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc.	Thomas J. Blanche, Malton, Yorkshire	94	None	2*s.* 6*d.* and 5*s.*	Report, every two years.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Seabridge Cottage, Ramsey, Isle of Man	135	2*s.* 6*d.*	Gentlemen 6*s.* Ladies 3*s.*	Yn Lioar Manninagh, quarterly
Manchester Geographical Society, 1885	Manch. Geog. Soc.	Eli Sowerbutts, F.R.G.S., 44 Brown Street, Manchester	800	None	Ordinary 1*l.* 1*s.* Associates 10*s.* 6*d.*	Journal, quarterly.
Manchester Geological Society, 1838	Manch. Geol. Soc.	Mark Stirrup, F.G.S., 36 George Street, Manchester	213	None	1*l*	Transactions, about nine parts per annum.

SELECTED LIST OF SOCIETIES, &c. (*continued*).

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Manchester Statistical Society, 1833	Manch. Stat. Soc.	25 Booth Street, Manchester. Francis E. M. Beardsall and G. H. Pownall	Ordinary 184	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Marlborough College Natural History Society, 1864	Marlb. Coll. N. H. Soc.	Marlborough College. E. Meyrick.	250	1*s.* 6*d.*	3*s.*	Report, annually.
Midland Union of Natural History Societies, 1877	Mid. Union	W. K. Parkes, 61 Cavendish Road, and Dr. Lawson Tait, The Crescent, Birmingham	2,000	—	—	'Midland Naturalist,' monthly.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	Prof. G. A. Lebour, Neville Hall, Newcastle-upon-Tyne	730	None	21*s.*, 42*s.*, 63*s.*	Transactions, about every two months.
North Staffordshire Naturalists' Field Club and Archæological Society, 1865	N. Staff. N. F. C. A. Soc.	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs.	374	5*s.*	5*s.*	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1885	N'ton. N. H. Soc.	The Museum, Guildhall Road, Northampton. H. N. Dixon	200	None	10*s.*	Journal, quarterly.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	W. B. Winnicott, Burton Joyce, near Nottingham	Honorary 8, Ordinary 137 Corresponding 8	None None None	None 5*s.* 2*s.* 6*d.*	Transactions and Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst.	J. Gardner, 3 County Place, Paisley	300	5*s.*	7*s.* 6*d.*	Report, annually.
Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc.	G. F. Tregelles, Devon and Cornwall Bank, Penzance	93	None	10*s.* 6*d.*	Report and Transactions, annually.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci.	Tay Street, Perth. S. T. Ellison	314	2*s.* 6*d.*	5*s.* 6*d.*	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, 20 King Street South, Rochdale	227	None	5*s.*	Transactions, occasionally.
Rochester Naturalists' Club, 1878	Rochester N. C.	John Hepworth, Union Street, Rochester	120	None	3*s.* 6*d.*, 5*s.*, and 10*s.*	'Rochester Naturalist,' quarterly.
Royal Scottish Geographical Society, 1884	R. Scot. Geog. Soc.	National Portrait Gallery, Edinburgh. A. Silva White	1,546	None	1*l.* 1*s.*	'Scottish Geographical Magazine,' monthly.
South African Philosophical Society, 1877	S. African Phil. Soc.	David Gill, F.R.S., Royal Observatory, Cape Town	72	None	2*l.*	Transactions, annually.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C.	W. G. Fretton, F.S.A., Hearsall Terrace, Chapel Fields, Coventry	66	2*s.* 6*d.*	5*s.*	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C.	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	About 200	10*s.*	10*s.*	Transactions, annually.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	James W. Davis, F.G.S., Chevinedge, Halifax	250	None	13*s.*	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union	W. Denison Roebuck, Sunny Bank, Leeds; and Rev. E. P. Knubley, Staveley Rectory, Leeds	410 and 2,517 Associates	None	10*s.* 6*d.*	Transactions, annually; 'The Naturalist,' monthly.

Index of the more important Papers, and especially those referring to Local Scientific Investigations, published by the above-named Societies during the year ending June 1, 1890.

*** This catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Pub-lished
Allison, R. A.	Weather Statistics in the Neighbourhood of Carlisle	Cumb. West. Assoc.	*Trans.*	XIV.	95	1889
Andrews, J. D. F.	The Wiring of Buildings for Electric Light	Glasgow Phil. Soc.	*Proc.*	XX.	225	,,
Brown, J.	Soap Bubbles	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1888-89	20	,,
Bullen, R.	Remarks on Temperature, Vegetation, &c., in the Royal Botanic Garden, Glasgow, 1888	Glasgow N. H. Soc.	*Trans.*	III.	25	,,
Burder, Dr. G. F.	Rainfall at Clifton, 1888	Bristol Nat. Soc.	*Proc.*	VI.	37	,,
Carter, W. Lower	Atmospheric Circulation	Leeds Geol. Assoc.	*Trans.*	V.	38	1890
Deane, Rev. G.	Note on the Effects of a so-called Waterspout at the Wittenham Hills, Berkshire	Birm. Phil. Soc.	*Proc.*	VI.	205	1889
Geikie, Prof. J.	The Evolution of Climate	R. Scot. Geog. Soc.	*Magazine*	,,	57	1890
Goodchild, J. G.	The Helm Wind	Cumb. West. Assoc.	*Trans.*	XIV.	43	1889
Gore, G.	On the Loss of Voltaic Energy of Electrolytes by Chemical Union	Birm. Phil. Soc.	*Proc.*	VI.	225	,,
Henderson, Rev. A.	Meteorological Observations	Paisley Phil. Inst.	*Report*	—	—	,,
Hewitt, C. E. B.	Meteorological Observations	Marlb. Coll. N. H. Soc.	,,	38	121	1890
Hodges, Rev. E. R.	The Spectroscope: its history and uses	Nott. Nat. Soc.	*Trans.*	For 1889	21	1889
Hookham, G.	On Permanent Magnet Circuits	Birm. Phil. Soc.	*Proc.*	VI.	208	,,
Hopkinson, J.	Report on the Rainfall in Hertfordshire in 1888	Herts N. H. Soc.	*Trans.*	V.	161	,,
,, ,,	Meteorological Observations taken at St. Albans during the years 1887 and 1888	,, ,,	,,	,,	187,193	,,
,, ,,	Climatological Observations taken in Hertfordshire in 1887 and 1888	,, ,,	,,	,,	203,209	,,
Kenward, J.	A Note on Hyper-radial and other recent Lenses for Lighthouse Illumination	Birm. Phil. Soc.	*Proc.*	VI.	213	,,
Lang, W., jun.	The Eastman Stripping Film and Roller Slide	Glasgow Phil. Soc.	,,	XX.	54	,,

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Law, F., and C. A. Markham	Meteorological Reports	N'ton. N. H. Soc.	*Journal*	5	201,222, 285,350	1889
Love, Dr. J. K.	On the Acoustics of Musical Sounds	Glasgow Phil. Soc.	*Proc.*	XX.	196	„
Marriott, W.	Report on the Helm Wind Inquiry	Cumb. West. Assoc.	*Trans.*	XIV.	107	„
Morris, T.	Some Causes of the Crystallisation of Iron	Liv'pool E. Soc.	„	X.	108	„
O'Neill, H. E.	A Note on some Astronomical Observations taken upon a Journey from Quilimane to the North Extremity of Lake Nyassa	R. Scot. Geog. Soc.	*Magazine*	V.	337	„
Poynting, Prof. J. H.	On a Mechanical Model illustrating the Residual Charge in a Dielectric	Birm. Phil. Soc.	*Proc.*	VI.	314	„
Rintoul, D.	Observations of Temperature at Clifton, 1888	Bristol Nat. Soc.	„	„	40	„
Sinclair, D.	Multiplex Telephony on Long Lines	Glasgow Phil. Soc.	„	XX.	128	„
Sorby, Dr. H. C.	On the Temperature of the Tidal Estuaries of the South-East of England	R. Scot. Geog. Soc.	*Magazine*	V.	589	„
Stuart, M. G.	Report on Rainfall, &c., in Dorset during 1888	Dorset N. H. A. F. C.	*Proc.*	X.	214	„
Sub-Committee, aided by H. Dean	On the Temperature of the River Stour	E. Kent N. H. Soc.	*Trans.*	3 & 4	138	„
Swanston, Wm.	Photography as an Aid to the Club's Work	Belfast Nat. F. C.	*Report and Proc.*	III.	130	„
Tanakadate, A.	Electro-magnetic Method of measuring the Magnetic Constants of the Earth's Field	Glasgow Phil. Soc.	*Proc.*	XX.	155	„
Tripp, W. B.	South American Rainfall South of the Tropics	R. Scot. Geog. Soc.	*Magazine*	V.	297	„
Watts, W.	Thermometrical Observations of Atmospheric Air and Water at Piethorne and Denshaw	Manch. Geol. Soc.	*Trans.*	XX.	271	„
Wells, J. G.	The Weather of 1888	Burt. N. H. Arch. Soc.	*Report*	For 1888-89	18	„

Section B.—CHEMICAL SCIENCE.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Atkinson, A. J.	On the Development of the Basic Process of Steel-making	Cardiff Nat. Soc.	*Report and Trans.*	XXI.	20	1890
Brierley, J.	Analysis of Contents of a British Burial Urn found at Dummer	Hants. F. C.	*Proc.*	III.	92	1889
Dickinson, J.	On Carbonic Acid Gas or Black Damp	Manch. Geol. Soc.	*Trans.*	XX.	256	„
Hewitt, J. T.	Analysis of Lias Mortar from Southampton Docks	Hants. F. C.	*Proc.*	III.	92	„
Johnstone, A.	Improved Methods of determining the Composition of Minerals by Blowpipe Analysis	Edinb. Geol. Soc.	*Trans.*	VI.	43	1890

Mayer, J.	Biographical Notice of Dr. Wm. Wallace, F.R.S.E.	,, ,,	,,	,,	314	,,
,, ,,	Joseph J. Coleman	,, ,,	,,	,,	328	,,
Me[illegible]la, Prof	The late Col. Russell's Contributions to Photography	Essex F. C.	*Essex Naturalist*	III.	117	,,
Turner, T.	On the Colours produced during the Tempering of Steel	Birm. Phil Soc.	*Proc.*	VI.	296	,,
		Section C.—GEOLOGY.				
Adamson, S. A.	Reports on Excursions	Leeds Geol. Assoc.	*Trans.*	V.	51–76	1890
,, ,,	At the Foot of the Wolds	Yorks. Nat. Union	*The Naturalist*	For 1889	179	1889
,, ,,	The Yorkshire Boulder Committee and its Third Year's Work	,, ,,	,, ,,	,,	293	,,
,, ,,	Geological Papers relating to the North of England	,, ,,	,, ,,	For 1890	12	1890
Beasley, H. C.	Presidential Address	Liv'pool Geol. Soc.	*Proc.*	VI.	11	1889
Bird, W. J.	Note on Seaton Carew Boring	Manch. Geol. Soc.	*Trans.*	XX.	263	,,
Brodie, Rev. P. B.	On the Predominance and Importance of the Blattidæ in the Old World	Warw. N. A. F. C.	*Proc.*	33	12	,,
Browett, A.	The Bath Oolite and Method of Quarrying	Birm. N. H. M. Soc.	*Mid. Naturalist*	XII.	187	,,
,, ,,	The Bath Oolite	Mid. Union	,, ,,	,,	,,	,,
Callaway, Dr. C.	Notes of the Quaternary Deposits of Shropshire	,,	,, ,,	XIII.	110	1890
Christy, R. W.	Notes on the Geology of the District around Chelmsford, with a List of the Mollusca from the Alluvium at Roxwell, Essex	Essex F. C.	*Essex Naturalist*	III.	171	1889
Clifford, W.	Additional Notes on Richmond Coal-field, Virginia	Manch. Geol. Soc.	*Trans.*	XX.	247	,,
Coates, H.	The Arrangement of the Perthshire Geological Collection in the Museum: Rock Specimens	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	105	,,
Cole, Rev. E. M.	Notes on the Driffield and Market Weighton Railway	Yorks. Geol. Poly. Soc.	*Proc.*	XI.	170	1890
Dalton, W. H.	On the Upper Clay of Walton Naze	Essex F. C.	*Essex Naturalist*	III.	223	1889
,, ,,	Foulness	,, ,,	,, ,,	,,	239	,,
Davis, J. W.	Biographical Notices of Eminent Yorkshire Geologists: No. iv. Hugh E. Strickland, F.R.S., &c.	Yorks. Geol. Poly. Soc.	*Proc.*	XI.	139	1890
,, ,,	Fossil Fish-remains from Carboniferous Shales at Cultra, Co. Down, Ireland	,, ,,	,,	,,	332	,,
,, ,,	Summary of Geological Literature relating to Yorkshire published during 1889	,, ,,	,,	,,	344	,,

Section C.—GEOLOGY (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Davison, C.	On the Secular Straining of the Earth	Birm. Phil. Soc.	*Proc.*	VI.	307	1889
Dawkins, Prof. W. Boyd	On the Discovery of Coal-measures near Dover	Manch. Geol. Soc.	*Trans.*	XX.	502	1890
De Rance, C. E.	Notes on the Geology of the Manchester Canal	Chesterf. Mid. Count. Inst.	*Trans. and Proc.*	I.	1	
" "	Underground Water Supply and River Floods	Yorks. Geol. Poly. Soc.	*Proc.*	XI.	200	"
Deacon, G. F.	The Glacial Geology of the Vyrnwy Valley	Liv'pool Geol. Soc.	"	VI.	86	1889
Deane, Rev. G.	The Geology and Travels of Jean André De Luc	Birm. Phil. Soc.	"	"	281	"
Dickson, E., and P. Holland	Examination of some Volcanic Rocks of the Isle of Man	Liv'pool Geol. Soc.	"	"	123	"
Dow, R.	Geological Notes on Loch Carron and West Ross-shire	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	98	"
Dowker, G.	The Probability of finding Coal in Kent	E. Kent N. H. Soc.	*Trans.*	3 & 4	130	"
Farrar, A., jun.	A Remnant of Pre-Glacial England; or Holiday Notes on the Cromer Forest Bed	Leeds Geol. Assoc.	"	V.	41	1890
Fitton, W. H.	One of Nature's Gems	" "	"	"	31	"
Fitzpatrick, J. J.	The Permian Conglomerate and other Palæozoic Rocks to the North of Morecambe Bay	Liv'pool Geol. Soc.	*Proc.*	VI.	42	1889
Forrester, J.	Sand	E. Scot. Union	"	For 1889	10	1890
Fox, H.	On the Junction of Hornblende Schist and Serpentine in the Ogo Dour District	Cornw. R. Geol. Soc.	*Trans.*	XI.	213	"
Goodchild, J. G.	The History of the Eden and of some Rivers adjacent	Cumb. West. Assoc.	"	XIV.	73	1889
Groves, T. B.	The Erosion of the Coast near Weymouth by the Action of the Sea	Dorset N. H. A. F. C.	*Proc.*	X.	180	"
Hardcastle, C. D.	The Physical Features of Ingleton	Leeds Geol. Assoc.	*Trans.*	V.	16	1890
Harker, Alfred	Petrological Notes on some Boulders from the Boulder Clays of East Yorkshire	Yorks. Geol. Poly. Soc.	"	XI.	300	"
" "	Notes on North of England Rocks	Yorks. Nat. Union	*The Naturalist*	For 1889	207	1889
" "	Bibliography for North of England, 1888: Geology and Palæontology	" "	" "	For 1890	121	1890
Haviland, A.	The Necessity for collecting and arranging the ascertained facts relating to the Glaciation of the Isle of Man	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	57	1889
" "	Aspects of Crags of the Manks Mountains in relation to the Glaciation of the Island	" "	" "	"	77	"
Henderson, J.	On the Succession of the Lower Carboniferous Series to the West of Edinburgh	Edinb. Geol. Soc.	*Trans.*	VI.	29	1890

Hick, T., & W. Cash	The Structure and Affinities of Lepidodendron	Yorks. Geol. Poly. Soc.	Proc.	[illegible]	[illegible]	,,
Holmes, T. V.	Notes on the Geology of Maldon and the Blackwater Estuary	Essex F. C.	*Essex Naturalist*	III.	111	1889
,, ,,	Recent Subsidences near Stifford, Essex	,, ,,	,, ,,	,,	183	,,
,, ,,	The Geology of South Essex	,, ,,	,, ,,	,,	214	,,
Hull, Prof. E.	On the probable Average Depth at which Coal is now being worked in the British Isles	Manch. Geol. Soc.	*Trans.*	XX.	417	,,
Jefferson, S.	Minerals as Gems and Precious Stones	Leeds Geol. Assoc.	,,	V.	45	1890
Johnston - Lavis, Dr. H. J.	The State of the Active Sicilian Volcanoes in September 1889	R. Scot. Geog. Soc.	*Magazine*	VI.	145	,,
Johnstone, A.	The Classification, Determination, Distribution, Origin, and Evolution of the Normal Micas	Edinb. Geol. Soc.	*Trans.*	,,	17	,,
Jones, Rev. E.	On the Further Exploration of a Cave at Elbolton, near Thorpe, in Craven	Yorks. Geol. Poly. Soc.	*Proc.*	XI.	307	,,
Kemp, J. T.	The Tufaceous Deposits of the Test and Itchen	Hants. F. C.	,,	III.	83	1889
Kermode, P. M. C.	Fossil Shells from the Boulder Clay and Sand, North Ramsey	I. of Man N. H. Soc.	*Yn Lioar Manninagh*	I.	96	,,
Kidson, E.	Further Evidences of Glacial Action in Snowdonia	Nott. Nat. Soc.	*Trans.*	For 1889	14	1890
Lamplugh, G. W.	On the Larger Boulders of Flamborough Head, Parts II. and III.	Yorks. Geol. Poly. Soc.	*Proc.*	XI.	231	,,
,, ,,	Glacial Sections near Bridlington	,, ,,	,,	,,	275	,,
Lomas, J.	Some Basaltic Dykes near Aros, Mull	Liv'pool Geol. Soc.	,,	VI.	69	1889
Lupton, Prof. A.	On Gold, Slate, and Salt Mines in Great Britain	Yorks. Geol. Poly. Soc.	,,	XI.	239	1890
McDakin, Capt.	Occurrence of Manganese in some Gravel Beds under Bigberry Wood, near Canterbury	E. Kent N. H. Soc.	*Trans.*	3 & 4	133	1889
,, ,,	Some Remarks on the Lower Greensand, attributing the continuous Formation of Glauconite to the Potash set free by decaying Vegetation	,, ,,	,,	,,	135	,,
McMurtrie, J.	Comparison of the Somerset Coal-field with the Coal-measures of Belgium and the North of France	Bath N. H. A. F. C.	*Proc.*	VII.	49	1890
Macnair, P.	The Arrangement of the Perthshire Geological Collection in the Museum: The Minerals	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	110	1889
,, ,,	On the Occurrence of supposed Annelid Tubes in the Quartzites of Perthshire	,, ,,	,, ,,	,,	116	,,
Mansel-Pleydell, J. C.	Note on *Elephas meridionalis* found at Dawlish	Dorset N. H. A. F. C.	*Proc.*	X.	1	,,
,, ,,	*Bos primigenius*	,, ,,	,,	,,	81	,,
,, ,,	*Crinodiosaurus Richardsoni*	,, ,,	,,	,,	171	,,

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Marr, J. E.	The Connection betwixt Yorkshire and Scandinavia	Yorks. Nat. Union	*The Naturalist*	For 1890	145	1890
Marshall, W. P.	Recent Fall of Rock at Niagara Falls	E. Kent N. H. Soc.	*Trans.*	3 & 4	139	1889
Mayou, R. W.	A Lump of Coal	Rochester N. C.	*Roch. Naturalist*	28	457	1890
Miller, Hugh	Supposed High-Level Shell Beds in E. Ross	Edinb. Geol. Soc.	*Trans.*	VI.	28	"
Mitchell, T. C.	On the Drift-Deposits of the Vale of Mowbray	Yorks. Geol. Poly. Soc.	*Proc.*	XI.	177	"
Moran, Dr. J.	Mammoth's Tooth recently found in the Drift Gravels at Larne Harbour	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1888-89	35	1889
Morgan, Prof. C. Ll.	The Geology of Tytherington and Grovesend	Bristol Nat. Soc.	*Proc.*	VI.	1	"
Morison, Dr. J.	Notes on the Chalk Rock	Herts N. H. Soc.	*Trans.*	V.	199	"
Morton, G. H.	Further Notes on the Stanlow, Ince, and Frodsham Marshes	Liv'pool Geol. Soc.	*Proc.*	VI.	50	"
" "	Some Faults exposed in Shafts and Borings in the Neighbourhood of Liverpool	" "	"	"	115	"
Nicholson, Prof. H. A.	Address on Recent Progress in Palæontology as regards Invertebrate Animals	Edinb. Geol. Soc.	*Trans.*	"	53	1890
Picton, Sir J. A.	Notes on the Local Historical Changes in the Surface of the Land in and about Liverpool	Liv'pool Geol. Soc.	*Proc.*	"	31	1889
" "	The Vyrnwy Valley: its Geological and Glacial History	" "	"	"	74	"
Piper, G. H.	Ludlow and Aymestry Rocks of the Silurian System	Woolhope N. F. C.	*Trans.*	—	39	1890
" "	On the Coal Measures of the Clee Hills	" "	"	—	82	"
" "	On the Passage Beds of the Old Red Sandstone at Ledbury	" "	"	—	136	"
" "	On the Old Red Sandstone as seen from the Sugarloaf Mountain in the county of Monmouth on the 10th of July, 1885	" "	"	—	313	"
Praeger, R. Ll.	Report on the Gravels and Associated Beds of the Curran, at Larne	Belfast Nat. F. C.	*Report and Proc.*	III.	198	"
" "	A Contribution to the Post-Tertiary Fauna of Ulster	" "	" "	"	215	"
Quine, Rev. J.	Geological Report for 1888–9	I. of Man. N. H. A. Soc.	*Yn Lioar Manninagh*	I.	73	1889
Reade, T. M.	The Advantage to the Civil Engineer of a Study of Geology	Liv'pool E. Soc.	*Trans.*	X.	36	"

	teristics and Causes					
„ „	Cause of the Colouration of Red Sandstones	Yorks. Nat. Union	*The Naturalist*	For 1890	1	1890
Reid, A. S.	On Time as a Geological Factor	E. Kent N. H. Soc.	*Trans.*	3 & 4	145	1889
Richardson, R.	Darwin's Geological Work	Edinb. Geol. Soc.	„	VI.	1	1890
Roeder, C.	Some Notes on the Barton Section of the Manchester Ship Canal	Manch. Geol. Soc.	„	XX.	285	1889
Rutley, F.	On a Specimen of Banded Serpentine from the Lizard, Cornwall	Cornw. R. Geol. Soc.	„	XI.	238	1890
Saunders, Rev. M. B.	On Mr. Mellard Reade's Work on Mountain Building	Bristol Nat. Soc.	*Proc.*	VI.	63	1889
Shipman, J.	The Geology of Nottingham	Nott. Nat. Soc.	*Trans.*	For 1889	26	1890
Shore, T. W., and J. W. Elwes	The New Dock Excavation at Southampton	Hants. F. C.	*Proc.*	III.	43	1889
Stirrup, M.	Delegate's Report of the British Association Meeting at Newcastle-upon-Tyne	Manch. Geol. Soc.	*Trans.*	XX.	394	„
„ „	On an alleged recent Discovery of a Fossil Forest in Scotland	„ „	„	„	412	„
„ „	On the Hydrology of the Causses of Languedoc; the Gorges of the Tarn, its Caverns and Subterranean Streams	„ „	„	„	446	1890
Stuart, M. G.	The Ridgway Fault	Dorset N. H. A. F. C.	*Proc.*	X.	55	1889
Tate, T.	Yorkshire Petrology: Part II.—Lamprophyres	Yorks. Geol. Poly. Soc.	„	XI.	311	1890
Teall, J. J. H.	Metamorphism in the Hartz and W. of England	Cornw. R. Geol. Soc.	*Trans.*	„	221	„
Timmins, A.	Notes on a few Borings and the Base of the New Red Sandstone in the Neighbourhood of Liverpool	Liv'pool Geol. Soc.	*Proc.*	VI.	56	1889
Tute, Rev. J. S.	Notes on some Singular Cavities in the Magnesian Limestone	Yorks. Geol. Poly. Soc.	„	XI.	182	1890
Vine, G. R.	Notes on British Eocene Polyzoa	„ „	„	„	154	„
„ „	A Monograph of Yorkshire Carboniferous and Permian Polyzoa. Part II.	„ „	„	„	184	„
„ „	Further Notes on the Polyzoa of the Lower Greensand and the Upper Greensand of Cambridge. Part II.	„ „	„	„	250	„
Walford, E. A.	On some Terraced Hill Slopes of the Midlands	N'ton. N. H. Soc.	*Journal*	5	303	1889
Walkden, R.	On the *Stigmaria ficoides* found in a Mine at Over Darwen	Manch. Geol. Soc.	*Trans.*	XX.	461	1890
Waller, T. H.	Note on a Granite containing Lithia	Birm. N. H. M. Soc.	*Mid. Naturalist*	XII.	154	1889
„ „	The Petrology of our Local Pebbles	„ „	„ „	„	174, 214, 286	„

Section C.—GEOLOGY (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Waller T H	Notes on some Rock Specimens collected in Norway by C. Pumphrey	Birm. N. H. M. Soc.	*Mid. Naturalist*	XII.	264	1889
" "	The Processes of Crystallisation in Rocks	" "	" "	XIII.	14	1890
Ward, T.	On the Salt Deposits of the United States of America and Canada	Manch. Geol. Soc.	*Trans.*	XX.	471	"
Watts, W.	Erratic Boulders and Boulder Clay in Castleshaw Valley	" "	"	"	265	1889
Whitaker, W.	Some Essex Well Sections. Part II.	Essex F. C.	*Essex Naturalist*	III.	44	"
" "	On a Deep Channel of Drift in the Valley of the Cam, Essex	" "	" "	"	140	"
" "	Hampshire Well Sections	Hants. F. C.	*Proc.*	"	17	"
Whitaker, W., and W. H. Dalton	List of Works on the Geology, &c., of Essex	Essex F. C.	*Essex Naturalist*	"	61	"
Whitley, N.	A Geological Note	Cornw. R. Geol. Soc.	*Trans.*	XI.	242	1890
Williams, H. W.	On Pembrokeshire as a Field for the Study of Geology	Manch. Geol. Soc.	"	XX.	426	1889
Winwood, Rev. H. H.	Rhætic Section at Luckington, and additional Notes on the Vobster Quarry	Bath N. H. A. F. C.	*Proc.*	VII.	45	1890
Woodward, A. S.	The Application of the Laws of Comparative Osteology to the Palæontology of the Vertebrata	Leeds Geol. Assoc.	*Trans.*	V.	27	"
" "	The Fossil Sturgeon of the Whitby Lias	Yorks. Nat. Union	*The Naturalist*	For 1890	101	"

Section D.—BIOLOGY.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Agar, Rev. W.	Spiders	Leicester Lit. Phil. Soc.	*Trans.*	II.	114	1890
Baker, J. G.	North Yorkshire: Studies of its Botany, Geology, Climate, and Physical Geography. (Third instalment)	Yorks. Nat. Union	"	3	145	1889
" "	Plants of the Infer-Arctic Zone on Ingleborough and Penyghent	" "	*The Naturalist*	For 1889	321	"
" "	On the Varieties of *Arenaria ciliata*	" "	" "	"	337	"
" "	Occurrence of *Carex strigosa* in North Yorkshire	" "	" "	For 1890	16	1890

Banks, E. R.	First Supplement to the 'Lepidoptera of the Isle of Purbeck'	Dorset N. H. A. F. C.	*Proc.*	X.	197	1889
Barclay, W.	Additions to the Flora of the Woody Island in 1888	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	102	"
Barling, Prof. G.	Tuberculosis, an Infectious Disease	Birm. Phil. Soc.	*Proc.*	VI.	233	"
Bell, Dr. J. V.	The Scientific Frontier	Rochester N. C.	*Roch. Naturalist*	25	409	"
Bennett, A.	Notes on the Flora of the Outer Hebrides	Glasgow N. H. Soc.	*Trans.*	III.	37	"
Binstead, Rev. C. H.	Some rare Mosses in Cumberland	Yorks. Nat. Union	*The Naturalist*	For 1890	16	1890
Blomefield, Rev. L.	Some peculiar Odours common in certain instances to both Animals and Plants	Bath N. H. A. F. C.	*Proc.*	VII.	13	"
Botanical Section	Phenological Observations, 1888	Burt. N. H. Arch. Soc.	*Report*	For 1888–9	14	1889
Boyd, D. A.	On the Occurrence in North Ayrshire of the Water Shrew and Otter	Glasgow N. H. Soc.	*Trans.*	II.	293	"
Brett, Dr. A. T.	Study of the Injuries and Diseases of Plants	Herts N. H. Soc.	"	V.	213	"
Broom, R.	On the Condition of the Auditory Ossicles of a Synotic Cyclopian Lamb	Glasgow N. H. Soc.	"	III.	86	1890
Brown, R.	Report to the East of Scotland Union by their Delegate to the Newcastle Meeting of the British Association	E. Scot. Union	*Proc.*	For 1889	57	"
Browne, M.	On a Fossil Fish (*Chondrosteus*) from Barrow-on-Soar hitherto recorded only from Lyme Regis	Leicester Lit. Phil. Soc.	*Trans.*	II.	17	1889
Bucknall, C.	The Fungi of the Bristol District	Bristol Nat. Soc.	*Proc.*	VI.	28	"
Bullen, R.	Remarks on Temperature, Vegetation, &c., in the Royal Botanic Garden, Glasgow, 1888	Glasgow N. H. Soc.	*Trans.*	III.	25	"
Burch, G. J.	On the Motion of Cilia of Animalcula as seen by flashing Light	Mid. Union	*Mid. Naturalist*	XIII.	114	1890
Burgess, E. W.	The Pocket Dredge	Birm. N. H. M. Soc.	" "	XII.	212	1889
Cambridge, Rev. O. P.	New and rare British Spiders	Dorset N. H. A. F. C.	*Proc.*	X.	107	"
" "	A new British Worm	" "	"	"	139	"
Carmichael, Dr. N.	Garnethill Scarlet Fever Epidemic	Glasgow Phil. Soc.	"	XX.	234	"
Catchpool, E.	The Flight of Birds and Insects	Birm. N. H. M. Soc.	*Mid. Naturalist*	XII.	221, 261	"
Clarke, H. S.	Entomological Report for 1888–9	I. of Man N. H. Soc.	*Yn Lioar Manninagh*	I.	158	1890
Clarke, J.	Some Plants peculiar to Essex, and on some Plants of Saffron Walden and Neighbourhood	Essex F. C.	*Essex Naturalist*	III.	274	1889
Clarke, W. E.	The Date of the Occurrence of *Emberiza cioides* at Flamborough	Yorks. Nat. Union	*The Naturalist*	For 1889	334, 356	"

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Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Clarke, W. E., and others	Is the Starling Double-brooded?	Yorks. Nat. Union.	*The Naturalist*	For 1889	366-373	1889
Cleland, Prof. J.	The Movements of the Joints of the Knuckles and Balls of the Toes	Glasgow Phil. Soc.	*Proc.*	XX.	62	,,
Collinge, W. E.	The Land and Freshwater Mollusca of Ingleton, Clapham, and District	Yorks. Nat. Union	*The Naturalist*	For 1890	109	1890
Cooke, Dr. M. C.	The Hymenomycetal Fungi of Epping Forest, with a Catalogue of the Species	Essex F. C.	*Essex Naturalist*	III.	248	1889
,, ,,	Suggestions on the Collecting and Study of the Minute Fungi of Essex	,, ,,	,, ,,	IV.	28	1890
Cordeaux, J.	Ornithological Notes from the Humber District in the Autumn of 1889	Yorks. Nat. Union	*The Naturalist*	For 1890	5	,,
Coy, F.	On Potato Disease	N'ton. N. H. Soc.	*Journal*	5	190	1889
Dallinger, Rev. W.	On Putrefactive Organisms	Bristol Nat. Soc.	*Proc.*	VI.	86	,,
Davis, J. P. A.	Report of the Yorkshire Marine Zoology Committee	Yorks. Nat. Union	*The Naturalist*	For 1890	3	1890
Dixon, H. N.	Northamptonshire Mosses: Fourth Supplementary List	N'ton. N. H. Soc.	*Journal*	5	189	1889
Dowker, G.	On the British Birds of East Kent, with List	E. Kent N. H. Soc.	*Trans.*	3 & 4	81	,,
,, ,,	Presence of *Falcaria Riviri* in East Kent	,, ,,	,,	,,	142	,,
Dresser, H. E.	Three Weeks on the Guadalquivir	Yorks. Nat. Union	*The Naturalist*	For 1890	17	1890
Druce, G. C.	The Flora of Northamptonshire	N'ton N. H. Soc	*Journal*	5	235, 249, 309	1889
Duncan, R.	Birds of Newcastle Town Moor	Yorks. Nat. Union	*The Naturalist*	For 1889	213	,,
Duncan, Dr. W.	*Trigonocephalus lanceolatus*: Notes on the West Indian Fer-de-Lance	Bristol Nat. Soc.	*Proc.*	VI.	44	,,
Ellacombe, Rev. Canon	The Vineyards of Somersetshire and Gloucestershire	Bath N. H. A. F. C.	,,	VII.	34	1890
Ellis, J. W.	Lepidopterous Fauna of Lancashire and Cheshire	Yorks. Nat. Union	*The Naturalist*	For 1890	49	,,
Ewing, P.	A Contribution to the Topographical Botany of the West of Scotland	Glasgow N. H. Soc.	*Trans.*	II.	309	1889
Eyre, Rev. W. L. W.	List of Hampshire Fungi: Part II.	Hants. F. C.	*Proc.*	III.	41	,,
Farquharson, Mrs.	Ferns and Mosses of the Alford District	E. Scot. Union	,,	For 1889	29	1890
		Rochester N. C.	*Roch. Naturalist*	26	437	1889

Fitch, E. A.	The late Christopher Parsons and his Collections	Essex F. C.	*Essex Naturalist*	III.	55	"
" "	Historical Notices of the Short-tailed Field-vole and Short-eared Owl in Essex	" "	" "	"	171	"
" "	Notes on the Raven in Essex	" "	" "	"	219	"
" "	Bird Migrations (Presidential Address)	" "	" "	IV.	1	1890
Fowler, Rev. W.	Lincolnshire Land and Clay Plants	Yorks. Nat. Union	*The Naturalist*	For 1889	353	1889
Galpin, Rev. A. J.	Observations on Plants	Marlb. Coll. N. H. Soc.	*Report*	38	54	1890
Gibbs, A. E.	Some Notes on the Lepidoptera of St. Albans and its Neighbourhood	Herts N. H. Soc.	*Trans.*	V.	181	1889
Griffiths, G. C.	Mimicry amongst the Lepidoptera	Bristol Nat. Soc.	*Proc.*	VI.	79	"
Grindon, L.	The Geographical Distribution of Plants	Manch. Geog. Soc.	*Journal*	5	299	1890
Grove, W. B., and J. E. Bagnall	The Fungi of Warwickshire	Mid. Union	*Mid. Naturalist*	XII.	190	1889
Harrison, Dr. A. J.	Do Snakes fascinate their Victims?	Bristol Nat. Soc.	*Proc.*	VI.	67	"
Harrison, J.	A Plea for the Starling	Yorks. Nat. Union	*The Naturalist*	For 1890	45	1890
Harting, J. E.	Of Hawks and Hounds in Essex in the Olden Times	Essex F. C.	*Essex Naturalist*	III.	189	1889
Hay, Col. H. M. D.	Notes on some Additions to the Birds and Nests recently placed in the Museum	Perth. Soc. N. Sci.	*Trans. and Proc.*	I.	91	"
Hepworth, J.	Rochester Grasses	Rochester N. C.	*Roch. Naturalist*	25	418	"
" "	Poisonous Plants of Rochester	" "	" "	27	449	1890
Herdman, Prof. W. A.	Brief Notes on the Marine Invertebrate Fauna of the Southern End of the Isle of Man	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	54	1889
Hervey, Rev. A. C.	Lepidoptera of Hampshire: Part III.	Hants F. C.	*Proc.*	III.	37	"
Hick, T.	Ludvig Klein on the Genus *Volvox*	Yorks. Nat. Union	*The Naturalist*	For 1890	87	1890
Hillier, T. J.	White Rhinoceros Horn	E. Kent N. H. Soc.	*Trans.*	3 & 4	139	1889
Hodgson, W.	Botanical Record for 1887–88	Cumb. West. Assoc.	"	XIV.	1	"
" "	The Botany of the Solway Shore, Parts II. & III.	" "	"	"	49	"
Hopkinson, J.	Report on Phenological Phenomena observed in Hertfordshire during the years 1887–88	Herts N. H. Soc.	"	V.	177	"
Horsley, Col.	Local Foraminifera	E. Kent N. H. Soc.	"	3 & 4	140	"
Jecks, C.	The Causes of the Difference in the Colour between the Flowers and Foliage of Tropical and of Temperate Regions	Bristol Nat. Soc.	*Proc.*	VI.	121	"
Johnson, Rev. W. F.	Irish Insects	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1888–9	16	"
Kelsall, J. E.	Hampshire Birds	Hants F. C.	*Proc.*	III.	16	"
Kermode, P. M. C.	Notes on Manks Mammals	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	43	"

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Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Kermode, P. M. C.	Manks Butterflies, with some Notes by the late E. Birchall, F.L.S., and Remarks	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	49	1889
" "	Zoological Report for 1888–89	" "	" "	"	70	"
Kew, H. W.	Shells of the Lincolnshire Coast	Yorks. Nat. Union	*The Naturalist*	For 1889	357	"
King, J. J. F. X.	A Contribution towards a Neuropterous Fauna of Ireland	Glasgow N. H. Soc.	*Trans.*	II.	259	"
Kirk, J. M.	Micro-Fauna and Micro-Flora of Upper Teesdale	Yorks. Nat. Union	*The Naturalist*	For 1889	292	"
Knubley, Rev. E. P.	The British Assoc. at Newcastle-upon-Tyne	" "	" "	"	345	"
Landsborough, D.	The Jay, Starling, and Kingfisher in Ayrshire	Glasgow N. H. Soc.	*Trans.*	II.	298	"
Laver, H.	The White-beaked Dolphin (*Delphinus albirostris*) in the River Colne	Essex F. C.	*Essex Naturalist*	III.	169	"
Lett, Rev. H. W.	Notes on some Desmids found in the North of Ireland	Belfast Nat. F. C.	*Report and Proc.*	"	137	"
" "	On the Cells of Mosses	" "	" "	"	214	1890
Lilford, Lord	Notes on the Birds of Northamptonshire	N'ton. N. H. Soc.	*Journal*	5	178, 207, 293	1889
" "	Notes on Birds in the Lilford Aviaries	" "	" "	"	258	"
Lofthouse, R.	Bird Notes from Tees District for Autumn and Winter, 1889–90	Yorks. Nat. Union	*The Naturalist*	For 1890	97	1890
McGregor, T. M.	A List of Additional Aculeate Hymenoptera collected in Perthshire during 1888	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	104	1889
Macpherson, Rev. H. A.	Occurrence of the Germon on the Cumberland Coast	Yorks. Nat. Union	*The Naturalist*	For 1890	15	1890
" "	The Storm Petrel in Summer	" "	" "	"	48	"
" "	The Tree Sparrow in the Lake District	" "	" "	"	92	"
" "	The Dotterel in Yorkshire	" "	" "	"	95	"
" "	The Shore-lark in Cumberland	" "	" "	"	115	"
Mann, W. K.	A few Notes on *Heliothis scutosa*	Bristol Nat. Soc.	*Proc.*	VI.	34	1889
Martindale, J. A.	The Lichens of Westmorland	Yorks. Nat. Union	*The Naturalist*	For 1890	157	1890
Masefield, J. B. R.	The Land and Freshwater Mollusca of North Staffordshire	Mid. Union	*Mid. Naturalist*	XII.	207	1889
Matthew, W.	History of the County Botany of Worcester	" "	" "	"	160	"

Meyrick, E.	Observations on Insects	Marlb. Coll. N. H. Soc.	*Report*	38	70	1890
Milne, W.	Rotifer as a Parasite or Tube-dweller	Glasgow Phil. Soc.	*Proc.*	XX.	48	1889
Morgan, Prof. C. Ll.	On the Perceptions of Animals	Bristol Nat. Soc.	„	VI.	116	„
Mosley, S. L.	Observations at Anston Stones	Yorks. Nat. Union	*The Naturalist*	For 1889	225	„
Mott, F. T.	The Ferns of Leicestershire	Leicester Lit. Phil. Soc.	*Trans.*	Vol. I., Pt. XII.	25	„
„ „	The Native Bulbs of Leicestershire	„ „	„	Vol. II.	68	1890
Murray, Rev. R. P.	Notes on Botany, chiefly Geographical	Dorset N. H. A. F. C.	*Proc.*	X.	47	1889
Neale, J. J.	Surface Fishes of the Bristol Channel	Cardiff Nat. Soc.	*Report and Trans.*	XXI.	8	1890
Nelson, T. H.	Bird Notes from Redcar & Teesmouth, 1889–90	Yorks. Nat. Union	*The Naturalist*	For 1890	99	„
Norman, G.	The Fauna of Bath as illustrated by the Duncan Local Museum	Bath N. H. A. F. C.	*Proc.*	VII.	1	„
Ormerod, Miss E. A.	The Hessian Fly and its Introduction into Britain	Herts N. H. Soc.	*Trans.*	V.	168	1889
Painter, Rev. W. H.	Notes on the Botany of Derbyshire	Yorks. Nat. Union	*The Naturalist*	For 1889	177	„
Perkins, R. C. L.	Wild Bees	Mid. Union	*Mid. Naturalist*	XII.	149	„
Pettigrew, A.	Gramineæ	Cardiff Nat. Soc.	*Report and Trans.*	XXI.	44	1890
Phillips, W. H.	A Gossip about British Ferns and their Varieties, with Notices of Local Finds	Belfast Nat. F.C.	*Report and Proc.*	III.	223	„
Porritt, G. T.	Radiated Varieties in Genus Arctia	Yorks. Nat. Union	*The Naturalist*	For 1889	233	1889
Poulton, E. B.	Theories of Heredity	Mid. Union	*Mid. Naturalist*	XII.	245	„
Powell, J.	Note on the Rearing of Cuckoos at Cassiobury, Watford	Herts N. H. Soc.	*Trans.*	V.	215	„
Praeger, R. Ll.	A Deep-sea Dredging Expedition	Belfast Nat. F.C.	*Report and Proc.*	III.	126	„
„ „	Recent Occurrence of the Stock Dove in the County of Antrim	„ „	„ „	„	211	1890
„ „	Three Days on Rathlin Island, with Notes on its Flora and Fauna	„ „	„ „	„	218	„
Pycraft, W. P.	A Contribution to the Pterylography of Birds' Wings	Leicester Lit. Phil. Soc.	*Trans.*	II.	123	„
Reid, J.	Life History of a Plant of *Daucus carota*	E. Kent N. H. Soc.	„	3 & 4	120	1889
„	The Progressive Development of the Ear through the Animal Series up to Aves	„ „	„	„	143	„
Richardson, N. M.	Notes on a few Fish lately taken on the Chesil Beach	Dorset N. H. A. F. C.	*Proc.*	X.	162	„
„ „	Description of a Species of *Epischnia* new to Science from Portland	„ „	„	„	192	„
Robertson, D.	Loch Fyne Herring	Glasgow N. H. Soc.	*Trans.*	III.	22	„

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Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Robertson, D.	Thirteen Cumacea from the Firth of Clyde	Glasgow N. H. Soc.	*Trans.*	III.	47	1889
Roebuck, W. D.	Bibliography for North of England of Papers published in—					
,, ,,	1886 (Birds)	Yorks. Nat. Union	*The Naturalist*	For 1889	161	,,
,, ,,	1884–1888 (Hemiptera)	,, ,,	,, ,,	,,	199	,,
,, ,,	1885–1888 (Reptiles)	,, ,,	,, ,,	,,	221	,,
,, ,,	1887 (Birds)	,, ,,	,, ,,	,,	249	,,
	1884–1889 (Hymenoptera)	,, ,,	,, ,,	For 1890	39	1890
Rome, W.	Threatened Destruction of Essex Oyster Culture	Essex F. C.	*Essex Naturalist*	IV.	41	,,
Rotheray, L.	The Discovery of *Arenaria gothica* in West Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1889	335	1889
Rowley, F. R.	A Brief Review of the Facts concerning *Hypopus*	Leicester Lit. Phil. Soc.	*Trans.*	Vol. I., Pt. XII.	15	,,
Roy, Dr. J.	The Desmids of the Alford District	E. Scot. Union	*Proc.*	For 1889	35	1890
Russell, G.	Notes on the Nepenthaceæ or Pitcher Plants	Glasgow N. H. Soc.	*Trans.*	II.	303	1889
Saunders, G. S.	Woodlice, Centipedes, and Snake Millipedes	E. Kent N. H. Soc.	,,	3 & 4	125	,,
Shenstone, J. C.	Report on the Flowering Plants growing in the neighbourhood of Colchester. Additions, 1889	Essex F. C.	*Essex Naturalist*	III.	222	,,
Sibley, Miss J.	Bees and Bee-keeping	Rochester N. C.	*Roch. Naturalist*	26	425	,,
Slater, Rev. H. H.	The Two-Barred Crossbill, an Addition to the Yorkshire Avifauna	Yorks. Nat. Union	*The Naturalist*	For 1889	314	,,
Smith, C. W.	The Birds of Central Ryedale, N.-E. Yorkshire	,, ,,	,, ,,	For 1890	325	,,
Smith, G. M.	The Water Cells of the Camel's Stomach	Bristol Nat. Soc.	*Proc.*	VI.	118	,,
Society, The.	Annual Report	Birm. N. H. M. Soc.	*Mid. Naturalist*	XIII.	49	1890
Somerville, A.	The Land and Freshwater Mollusca of Iona	Glasgow N. H. Soc.	*Trans.*	II.	296	1889
,, ,,	Notes on the Flora of Barra and South Uist	,, ,,	,,	III.	31	,,
,, ,,	*Isocardia cor*, L., in the West of Scotland	,, ,,	,,	,,	42	,,
Strickland, W. W.	Notes on Fungi, with List of Species collected in East Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1889	183	,,
Stuart, M. G.	Report on the Rainfall and Observations on the Flowering of Plants and Appearances of Birds and Insects in Dorset during 1888	Dorset N. H. A. F. C.	*Proc.*	X.	214	,,
Swan, A. P.	The Fungus of Salmon Disease	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1888-89	54	,,

Talbot, Rev. T.	Marine Algæ, especially of Douglas Bay, with List	Isle of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	82	1890
Thornewill, Rev. C. F., and T. Gibbs, jun.	Calendar of Nature, 1888	Burt. N. H. A. Soc.	*Report*	For 1888-89	22	1889
Thomson, Jas.	On the Detection of Mural Pores in the Genus *Alveolites*	Glasgow Phil. Soc.	*Proc.*	XX.	116	"
Trail, Prof. J. W. H.	Report for 1889 on the Fungi of the East of Scotland	E. Scot. Union	"	For 1889	49	1890
" "	The Work of the British Association in 1889 in relation to Scottish Scientific Societies	" "	"	"	68	"
" "	Revision of the Scotch Perisporiaceæ	Glasgow N. H. Soc.	*Trans.*	III.	9	1889
Trusted, C. J.	Talpa: or Remarks on the Habits of the Mole	Bristol Nat. Soc.	*Proc.*	VI.	56	"
Tute, Rev. J. S.	Microscopic Fauna and Flora of Markington, Mid-West Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1890	151	1890
Vaughan, H.	The Lepidoptera of Leigh, Essex, and its Neighbourhood	Essex F. C.	*Essex Naturalist*	III.	123	1889
Various	Report on Excursions, 1887	Glasgow N. H. Soc.	*Trans.*	II.	322	"
Waddell, Rev. C. H.	Some Notes on Plant Life	Belfast Nat. F. C.	*Report and Proc.*	III.	212	1890
Warner, F. I.	New Hampshire Moth	Hants F. C.	*Proc.*	"	16	1889
White, Dr. F. B.	Opening Address	Perths. Soc. Nat. Sci.	*Trans. and Proc.*	I.	xxxv.	"
" "	Presidential Address	" "	" "	"	xliv.	"
White, J. W.	Flora of the Bristol Coalfield	Bristol Nat. Soc.	*Proc.*	VI.	18	"
Whitlock, F. B.	Notes on the Tree Sparrow	Yorks. Nat. Union	*The Naturalist*	For 1890	43	1890
" "	Autumn Bird Notes from Notts	" "	" "	"	47	"
" "	Some further Notes on the Tree Sparrow	" "	" "	"	155	"
Williams, J. W.	Two hitherto undescribed Varieties of *Limnæa stagnalis* (Linn.)	Mid. Union	*Mid. Naturalist*	XII.	164	1889
Wilson, A. S.	The Dispersion of Seeds and Spores: Part I.	Glasgow N. H. Soc.	*Trans.*	III.	50	1890
Wilson, W., jun.	Observations on the Growth of Reed Canary Grass (*Phalaris arundinacea*)	E. Scot. Union	*Proc.*	For 1889	46	"
Windle, Prof. B. C. A.	On some recent Researches in connection with the Maturation, Fertilisation, and Segmentation of the Ovum	Birm. Phil. Soc.	"	VI.	243	1889
" "	Notes on certain Malformations in Fishes	" "	"	"	318	"
Wood, Rev. F. H.	Notes on some Aquatic Coleoptera	N'ton. N. H. Soc.	*Journal*	5	229	"
Woodd, T. B.	Plants of Langstrothdale, Mid-West Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1889	271	"
Wotton, F. W.	On the Occurrence of *Achatina acicula* in the Cardiff District in two new Localities	Cardiff Nat. Soc.	*Report and Trans.*	XXI.	42	1890

Section E.—Geography.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Abercromby, Hon. J.	The Wall of Derbend	R. Scot. Geog. Soc.	*Magazine*	VI.	135	1890
Argyll, Duke of	Border Lands between Geology and Geography	„ „	„	„	169	„
Bailey, Ald. W. H.	Prehistoric Chat Moss, and a New Chapter in the History of the Manchester and Liverpool Railway	Manch. Geog. Soc.	*Journal*	5	119	„
Bell, Col. M. S.	Around and about Armenia	R. Scot. Geog. Soc.	*Magazine*	VI.	113	„
Blaikie, Professor W. G.	Southern California Past and Present	„ „	„	„	187	„
Colbeck, Rev. A.	The Sea and Shores of Azov	Manch. Geog. Soc.	*Journal*	5	29	1889
De Seidlitz, N.	The Province of Elizavetopol	R. Scot. Geog. Soc.	*Magazine*	V.	368	„
Dingelstedt, V.	The Geography of the Caucasus	„ „	„	„	348	„
Du Chaillu, P. B.	Scandinavia: The Vikings and the Geography of their Times	„ „	„	VI.	225	1890
Gibson, H.	Taranaki	Manch. Geog. Soc.	*Journal*	5	173	„
Gordon, Rev. A.	Notes of Spanish Travel	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1888-89	24	1889
Grissinger, K.	The Snowline of the Tatra Mountains	Manch. Geog. Soc.	*Journal*	5	198	1890
Guillaume, Chev. H.	The Travels of Colonel A. R. P. Labre, Carlos Fry, and others, in Peru and Bolivia	„ „	„	„	315	„
„ „	Recent Explorations in Peru and Bolivia	R. Scot. Geog. Soc.	*Magazine*	VI.	234	„
Guppy, H. B.	The Cocos-Keeling Islands	„ „	„	V.	281, 457, 569	1889
„ „	Tridacna Pearls	„ „	„	„	319	„
„ „	The South Coast of West Java	„ „	„	„	625	„
Hovgaard, Capt. A.	The Kara Sea and the Route to the North Pole	R. Scot. Geog. Soc.	*Magazine*	VI.	25	1890
Ingleby, J.	Ceylon's Isle	Leeds Geol. Assoc.	*Trans.*	V.	9	„
Kropotkin, Prince	What Geography ought to be	Manch. Geog. Soc.	*Journal*	5	356	„
Lugard, Captain F. L.	Lake Nyassa and Central Africa	„ „	„	„	347	„
Lea, T. S.	Oceanic Islands	Birm. N. H. M. Soc.	*Mid. Naturalist*	XIII.	88	„
Lumholtz, C.	The Present and Future of Queensland	R. Scot. Geog. Soc.	*Magazine*	V.	527	1889
Mackinder, H. J.	The Physical Basis of Political Geography	„ „	„	VI.	78	1890

Maples, Ven. Archdeacon	Lukoma: an Island in Lake Nyassa	Manch. Geog. Soc.	*Journal*	5	59	1889
Marvin, C.	Geography	,, ,,	,,	,,	365	1890
Mill, Dr. H. R.	Scientific Earth Knowledge as an Aid to Commerce	R. Scot. Geog. Soc.	*Magazine*	V.	302	1889
,, ,,	The Vertical Relief of the Globe	,, ,,	,,	VI.	182	1890
Millson, A.	Lagoons of the Bight of Benin, West Africa	Manch. Geog. Soc.	*Journal*	5	333	,,
Mohn, Prof. H.	The Physical Condition of Barents Sea	R. Scot. Geog. Soc.	*Magazine*	V.	535	1889
Molesworth, J. M.	Notes of Travel from Shanghai to St. Petersburg	Manch. Geog. Soc.	*Journal*	5	36	,,
Montefiore, A.	Florida and the English	,, ,,	,,	,,	129	1890
Murray, Dr. J.	On Marine Deposits in the Indian, Southern, and Antarctic Oceans	R. Scot. Geog. Soc.	*Magazine*	V.	405	1889
Nansen, Dr. F.	A Journey across the Inland Ice of Greenland from East to West	,, ,,	,,	,,	393	,,
Owen, Rev. G.	Peking and the Pekingese	Manch. Geog. Soc.	*Journal*	5	1	,,
Parr, Rev. T.	Fernando Po, West Africa	,, ,,	,,	,,	20	,,
Pelly, Gen. Sir L.	Anniversary Address—Africa: British and other Spheres of Influence	R. Scot. Geog. Soc.	*Magazine*	VI.	1	1890
Rankin, D. J.	The Zambezi Delta	,, ,,	,,	V.	475	1889
Rippon, J.	The Portuguese Possessions of the South-West Coast of Africa, and particularly of Angola	Manch. Geog. Soc.	*Journal*	5	359	1890
Rogers, J. C.	Chili: its present Position and future Prospects	Glasgow Phil. Soc.	*Proc.*	XX.	240	1889
Silberbach, J. H.	On the Teaching of Elementary Commercial Geography in Primary and Secondary Schools, and in a minor degree of Elementary Technical Instruction	Manch. Geog. Soc.	*Journal*	5	151	1890
Stevenson, J.	Great Britain and Portugal in East Africa	R. Scot. Geog. Soc.	*Magazine*	V.	371	1889
Sullivan, H. N.	The Resources of Siberia and the Practicability of the Sea Route	Manch. Geog. Soc.	*Journal*	5	367	1890
Thomson, B.	Narrative of an Exploring Expedition to the Eastern Part of New Guinea	R. Scot. Geog. Soc.	*Magazine*	V.	513	1889
Thomson, J.	Some Impressions of Morocco and the Moors	Manch. Geog. Soc.	*Journal*	5	101	1890
Thomson, J. P.	The Island of Kadavu	R. Scot. Geog. Soc.	*Magazine*	V.	638	1889
White, A. Silva	On the Achievements of Scotsmen during the Nineteenth Century in the Fields of Geographical Exploration and Research	,, ,,	,,	,,	480, 540, 595	,,
Workman, T.	A Visit to Singapore	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1888-89	30	,,

Section F.—Economic Science and Statistics.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Aikman, C. M.	Agricultural Education in this Country and Abroad	Glasgow Phil. Soc.	*Proc.*	XX.	133	1889
Bailey, W. F.	Forestry in Ireland	Stat. Soc. Ireland	*Journal*	IX.	429	"
Chalmers, J.	A Scheme of Cremation suited to the Requirements of Glasgow	Glasgow Phil. Soc.	*Proc.*	XX.	193	"
Coffey, G.	The proposed Technical Instruction Bill and the Science and Art Department	Stat. Soc. Ireland	*Journal*	IX.	403	"
Davidson, M.	State Purchase of Land in Ireland	Glasgow Phil. Soc.	*Proc.*	XX.	281	"
Dyer, H.	On the Training of Architects	" "	"	"	66	"
Eick, W.	The Reduction of the Rate of Interest since 1870, with Remarks as to the Probable Amount of Incumbrances on Irish Land and the Possible Fund available for their Payment	Stat. Soc. Ireland	*Journal*	IX.	App. II.	"
Finlayson, Dr. J.	Proposal for securing Uniformity of Action in the Exclusion from Day Schools of Children coming from Families affected with Contagious Diseases	Glasgow Phil. Soc.	*Proc.*	XX.	216	"
Flinn, D. E.	Irish Intellect and its Geographical Distribution	Stat. Soc. Ireland	*Journal*	IX.	393	"
Gairdner, C.	An Examination of the Report of the Royal Commission on the recent Changes in the relative Values of Gold and Silver	Glasgow Phil. Soc.	*Proc.*	XX.	264	"
Galloway, J. R.	The Evidence of Statistics in relation to our Social Condition	Manch. Stat. Soc.	*Trans.*	For 1889-90	25	1890
Gibson, R. H.	Statistics of New Zealand for 1888	" "	"	"		"
Grimshaw, T. W.	Child Mortality in Dublin	Stat. Soc. Ireland	*Journal*	IX.	App.III	1889
Guthrie, E.	Local Government	Manch. Stat. Soc.	*Trans.*	For 1889-90	1	1890
Hall, H.	On the Duration of our Coal Supply	Manch. Geol. Soc.	"	XX.	379	1889
Hallett, H. S.	Indian Railways and British Trade	Manch. Geog. Soc.	*Journal*	5	181	1890
Honeyman, J.	Sanitary and Social Problems	Glasgow Phil. Soc.	*Proc.*	XX.	25	1889
Howatt, J.	On Mutual Gables	" "	"	"	213	"
Ingram, J. K.	Memoir of William Neilson Hancock, LL.D., Q.C.	Stat. Soc. Ireland	*Journal*	IX.	384	"
Matheson, R. E.	The Mechanism of Statistics	" "	"	"	App. I.	"
Miller, A. L.	Memoir of James Sellars, Architect	Glasgow Phil. Soc.	*Proc.*	XX.	40	"

Mills, Rev. H. V.	Home Colonisation	Manch. Stat. Soc.	*Trans.*	For 1889-90	51	1890
Moloney, Governor	Cotton Interests, Foreign and Native, in Yoruba, and generally in West Africa	Manch. Geog. Soc.	*Journal*	5	255	„
Murphy, T. J.	A Suggestion on Coinage	Stat. Soc. Ireland	„	IX.	381	1889
Naden, Miss C. W.	The Principles of Sociology	Birm. N. H. M. Soc.	*Mid. Naturalist*	XIII.	27	1890
O'Brien, M.	Recent Statistics of French Rural Economy	Stat. Soc. Ireland	*Journal*	IX.	363	1889
Russell, Dr. J. B.	On the 'Ticketed' Houses of Glasgow	Glasgow Phil. Soc.	*Proc.*	XX.	1	„
Smith, Rev. A. J.	The Educational Work of the French Revolutionists, 1789–1795	Birm. Phil. Soc.	„	VI.	265	„
Smith, W. A.	Fisheries in relation to General Civilisation and Progress	Glasgow Phil. Soc.	„	XX.	87	„
Tannahill, T. F.	Air, Water, Food	Rochester N. C.	*Roch. Naturalist*	27	441	1890
Tonkin, J.	The Steam Boilers Bill	Cornw. Min. Assoc. Inst.	*Trans.*	II.	76	1889
Whyte, J.	The Cost of our Drinking Customs	Manch. Stat. Soc.	„	For 1889-90	67	1890
Younger, R. T.	Land Ownership in Scotland	Glasgow Phil. Soc.	*Proc.*	XX.	177	1889
	Section G.—MECHANICAL SCIENCE.					
Bamford, C. F.	Air-brakes	Liv'pool E. Soc.	*Trans.*	IX.	57	1889
Beloe, C. H.	The Purification of Water and Sewage by the Magnetic Spongy Carbon Process	„ „	„	X.	118	„
Blair, W. N.	Salt Water Supply to the Public Baths, Bootle	„ „	„	„	45	„
Brighthouse, A. W.	Some recent Experiments on Iron and Steel and Riveted Joints	„ „	„	IX.	1	„
„ „	Application of Atmospheric Air to produce Motive Power	„ „	„	X.	54	„
Coke, G. E.	A recent Boring at Chesterfield with the Diamond Drill	Chesterf. Mid. Count. Inst.	*Trans. and Proc.*	I.	17	1890
Cotterell, A. P. J.	Some Remarks on Sewerage Systems	Bristol Nat. Soc.	*Proc.*	VI.	93	1889
Crawford, G. E.	The Eiffel Tower	„ „	„	„	142	„
Darbishire, C. H.	President's Inaugural Address	Liv'pool E. Soc.	*Trans.*	X.	1	„
Farren, G.	The Construction of small Breakwaters, and the Silting they give rise to	„ „	„	„	92	„
Greenwell, G. C., jun.	Description of a Patent Screen	Manch. Geol. Soc.	„	XX.	440	1890
Hoey, D. G.	The Science of Ventilation as applied to Inhabited Interiors	Glasgow Phil. Soc.	*Proc.*	„	308	1889

Section G.—MECHANICAL SCIENCE (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Pub-lished
Honeyman, J.	On House Drains without Ventilation	Glasgow Phil. Soc.	*Proc.*	XX.	309	1889
Lewis, G.	Presidential Address	Chesterf. Mid. Count. Inst.	*Trans. and Proc.*	I.	11	1890
McCurrick, J. M.	The Warehousing of Grain	Bristol Nat. Soc.	*Proc.*	VI.	124	1889
Marshall, W. P.	Modern Railways and Railway Travelling	Birm. Phil. Soc.	"	"	183	"
Nelson, D. M.	Proposed Scheme for the Collection, Treatment, and Disposal of the Sewage of Glasgow	Glasgow Phil. Soc.	*Proc.*	XX.	311	"
Sang, W.	Some Remarks upon a Steamship Performance Diagram	Liv'pool E. Soc.	*Trans.*	X.	106	"
Sauer, J. A.	Flood Gates and Weirs on the River Weaver	" "	"	IX.	17	"
Turner, J. H. T.	Filtration of Sewage	" "	"	"	28	"
Webster, J. J.	Steam Boiler Explosions	" "	"	"	41	"
West, H. H.	Steel in the hands of the Naval Architect	" "	"	X.	68	"
Wyld, R. S., jun.	The Laying of large Mains	" "	"	"	20	"

Section H.—ANTHROPOLOGY.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Pub-lished
Andrews, W.	On Cup and Circle Marks on Church Walls in Warwickshire and Neighbourhood	Warw. N. A. F. C.	*Proc.*	33	5	1889
Balfour, H.	The Origin of Decorative Art as illustrated by the Art of Modern Savages	Mid. Union	*Mid. Naturalist*	XIII.	105	1890
Bloxam, M. H.	A short Dissertation on Runes	Warw. N. A. F. C.	*Proc.*	33	33	1889
Bourke, W. W. L.	Discovery of an Ancient British Canoe in Hampshire	Hants F. C.	"	III.	90	"
Buckland, Miss A. W.	Prehistoric Trephining	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	86	"
Chancellor, F.	Old Chelmsford	Essex F. C.	*Essex Naturalist*	III.	143	"
Cheetham, W.	On a Boulder with Cup and Ring Markings at Horsforth	Yorks. Geol. Poly. Soc.	*Proc.*	XI.	175	1890
Clarke, J.	Notes on Bartlow Hills, Essex	Essex F. C.	*Essex Naturalist*	III.	288	1889
Colville, Dr. J.	Primitive Aryan Civilisation	Glasgow Phil. Soc.	*Proc.*	XX.	97	"

Eve, A. S., and E. Meyrick	An Experiment in assigning Marks for Physical Measurements	Marlb. Coll. N. H. Soc.	*Report*	38	94	1890
Gardner, C. T.	The Coins of China	Manch. Geog. Soc.	*Journal*	5	233	"
Gray, Wm.	Vestiges of Early Man in Antrim and Down	Belfast Nat. F. C.	*Report and Proc.*	III.	136	1889
Hogg, A.	The Antiquities of Davan and Kinnord	E. Scot. Union	*Proc.*	For 1889	15	1890
Jebb, Dr. R. C.	On present Tendencies in Classical Studies	Glasgow Phil. Soc.	"	XX.	168	1889
Jeffcott, J. M.	Presidential Address	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	153	1890
Kermode, P. M. C.	A Cinerary Urn from Ballascyr, Andreas	" "	" "	"	52	1889
" "	Additional Notes on the Ballakaighen Canoe	" "	" "	"	78	"
" "	Flint Implements from the Brooghs, North Ramsey	" "	" "	"	131	1890
Knowles, J. J. W.	The Theories as to the Variations of Race in Mankind	Leicester Lit. Phil. Soc.	*Trans.*	Vol. I., Pt. XII.	6	1889
Laver, H.	Discovery of Celtic Urns at Colchester	Essex F. C.	*Essex Naturalist*	III.	116	"
MacCormac, Dr. J.	Man's Food and Dietetics	Belfast N. H. Phil. Soc.	*Rep. and Proc.*	For 1888-89	38	"
Maynard, G. N.	Ancient Labyrinth or Maze at Saffron Walden, and on the Antiquity of Mazes in general	Essex F. C.	*Essex Naturalist*	III.	244	"
" "	Human Skin nailed upon Church Doors at Hadstock, Copford, and elsewhere	" "	" "	"	292	"
Meyrick, E.	Anthropometrical Statistics	Marlb. Coll. N. H. Soc.	*Report*	38	142	1890
Milligan, S. F.	The Sepulchral Structures and Burial Customs of Ancient Ireland	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1888-89	43	1889
Moloney, Governor	On the Melodies of Volof, Mandingo, Ewe, Yoruba, and Houssa People of West Africa	Manch. Geog. Soc.	*Journal*	5	277	1890
Moore, A. P.	Characters and Character Drawing	Leicester Lit. Phil. Soc.	*Trans.*	II.	7	1889
Mortimer, J. R.	Pre-history of the Village of Fimber: Part I.	Yorks. Geol. Poly. Soc.	*Proc.*	XI.	217	1890
Pengelly, W.	An Old Man and Woman; Human Bones in a Scrobicularia Bed at Newton Abbot, Devon	Edinb. Geol. Soc.	*Trans.*	VI.	37	"
Prowse, Dr. A. B.	Voice, Language, Phonetic Spelling	Bristol Nat. Soc.	*Proc.*	"	153	1889
Royle, Dr.	Note on King Orry's Grave	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	99	"
Somerset, Rev. C. E.	Cree Indians of Calgary	Manch. Geog. Soc.	*Journal*	5	194	1890
Stirrup, M.	On the Ancient Canoe found at Barton-upon-Irwell	Manch. Geol. Soc.	*Trans.*	XX.	295	1889
Swinnerton, F.	The Early Neolithic Cists and Refuse Heap at Port St. Mary	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	137	1890
Udal, J. S.	Dorsetshire Folk Speech and Superstitions	Dorset N. H. A. F. C.	*Proc.*	X.	19	1889

Third Report of the Committee, consisting of the Hon. RALPH ABERCROMBY, Dr. A. BUCHAN, Mr. J. Y. BUCHANAN, Mr. J. WILLIS BUND, Professor CHRYSTAL, Mr. D. CUNNINGHAM, Professor FITZGERALD, Dr. H. R. MILL (*Secretary*), Dr. JOHN MURRAY (*Chairman*), Mr. ISAAC ROBERTS, Dr. H. C. SORBY, *and the* Rev. C. J. STEWARD, *appointed to arrange an investigation of the Seasonal Variations of Temperature in Lakes, Rivers, and Estuaries in various parts of the United Kingdom in co-operation with the local societies represented on the Association.*

AS in previous years, the work of this Committee was carried on by correspondence and by occasional informal meetings of a few of the members. The Committee was reappointed at the Newcastle meeting of the Association in 1889 without a grant, and its work has been carried on at the expense of the Secretary. Four new observing stations were instituted, and regular observations have been carried on at thirty, at least, of the stations existing at the date of last report.

Most of the original observers for the Committee have, for various reasons, been obliged to cease observing, and many of them, on account of their other duties, have only been able to keep occasional records of temperature. Mr. G. Taylor, gardener to His Grace the Duke of Argyll, at Inveraray, and Mr. J. Paterson, Almond Bank, commenced the daily observation of temperature in rivers at the beginning of January 1888, and are prepared to carry on the work. Thanks to the interest taken in the subject by many of the Corresponding Societies of the Association, a number of very valuable records are now being obtained, with a continuity and completeness which could not be expected from unattached observers. The Dumfries and Galloway Natural History Society, through the Rev. Wm. Andson, an enthusiastic meteorologist, has accumulated many data regarding the rivers Nith and Dee and their estuaries in the Solway Firth. Mr. Andson has discussed and summarised the earlier observations in a very interesting paper presented to his Society. The Bristol Channel, analogous in many respects to the Solway, has received attention from the Bristol Naturalists' Society and the Cardiff Naturalists' Society, each of which employs several observers, the former having the English and Welsh Grounds Lightship and the latter the Breaksea Lightship as observing stations. The East Kent Natural History Society maintains observations on the Stour and the Medway, and Colonel W. H. Horseley, R.E., who takes a keen interest in the subject, has sent in a valuable summary of the results already obtained to the Committee. The Manchester Geological Society has printed the complete series of observations made under its auspices by Mr. W. Watts, F.G.S., on the Denshaw and Piethorn reservoirs, near Oldham. Mr. J. Reginald Ashworth, of the Rochdale Literary and Scientific Society, has made similar observations on the reservoirs at Cowm, Clay Lane, and Springmill, and Mr. Eunson has made an admirable comparison of the temperature of the Northampton reservoir and the river Nene, under the auspices of the Northampton Natural History Society. Mr. H. Preston, for the Grantham Scientific Society, and Mr. F. E. Lott, for the Burton-on-Trent Natural History Society, are investigating the conditions of their neighbouring rivers. The Marlborough College Natural History Society has also undertaken similar work. To all of these Societies, to their secretaries, and especially to their observers, the Committee has to record deep obligations.

The object which the Committee has in view is to investigate the changes in the temperature of exposed water-surfaces with the seasons, and the modifying influences of situation, rapidity of flow, and other conditions. The rivers in which observations have now been made differ widely in geographical and climatic condition, the cool, equable climate of Caithness and the great range of temperature experienced in Kent being extreme types. In addition to the observations detailed in the accompanying tables, the Committee will have access to a good deal of previously printed but undiscussed observations, and to an immense mass of unpublished observations in the keeping of the Scottish Meteorological Society. It is also hoped that the observations of the Fishery Board for Scotland, the Tweed River Commission, the Severn Fishery Board, and other public bodies which have been induced by various members of this Committee to undertake observations will become available for discussion. Impressed with a sense of the importance of this research to the science of Meteorology, and incidentally to many practical matters, the Committee appeals to the British Association for assistance in discussing these observations, asking to be reappointed, with a grant of 50*l.*, for the purpose of drawing up a complete report.

Statement of Observations Collected by the Committee.

River, &c.	Observers	Period of Observations
	I.—IN ENGLAND.	
Lugg . . .	Mr. A. Ward, Aymestrey .	Apl. 25, 1889–Sept. 27, 1889
Avon (Warwick) .	Mr. G. Duke, Hill Wooton .	—
Severn . . .	Mr. E. Collens, Stourport .	Mar. 25, 1889–May 31, 1890
[1] Taff . . .	Mr. Pettigrew, Cardiff . .	Feb. 17, 1889 (in progress)
[1] Breaksea Lightship	Mr. Walters	Mar. 1, 1889 „ „
[2] Avon . . .	Mr. S. W. Sutcliffe, Clifton .	—
[2] English and Welsh Grounds Lightship	Messrs. Pain and Bartlett .	Feb. 6, 1889 (in progress)
[3] Kennet . . .	Messrs. W. B. and H. G. Maurice, Marlborough	Dec. 9, 1888 (in progress)
[4] Stour . . .	Mr. H. Dean, Canterbury .	Dec. 13, 1888 „ „
[4] Medway . . .	Sergeant-Major Bolton, New Brompton	Mar. 25, 1889 „ „
Nidd . . .	Mr. G. Paul, Knaresborough .	Mar. 16, 1889 „ „
Dove . . .	Mr. H. H. Brindley, Uttoxeter	Mar. 17, 1889–Nov. 27, 1889
[5] Trent . . .	Mr. F. E. Lott, Burton . .	Jan. 7, 1889 (in progress)
[6] Nene and reservoir.	Mr. Eunson, Northampton .	Jan. 1, 1889 „ „
[7] Witham . . .	Mr. H. Preston, Grantham .	Apl. 2, 1889 „ „
[8] Denshaw and Piethorn Reservoirs	Mr. W. Watts, F.G.S., Oldham	Jan. 1, 1889 „ „

[1] Under the care of the Cardiff Naturalists' Society; Mr. R. W. Atkinson, Secretary.
[2] Under the care of the Bristol Naturalists' Society; Mr. A. Leipner, Secretary.
[3] Under the care of the Marlborough College Natural History Society.
[4] Under the care of the East Kent Natural History Society; special oversight of Col. W. H. Horseley, R.E.
[5] Under the care of the Burton-on-Trent Natural History Society.
[6] Under the care of the Northampton Natural History Society.
[7] Under the care of the Grantham Scientific Society.
[8] Under the care of the Manchester Geological Society; Mr. Mark Stirrup, F.G.S., Secretary.

STATEMENT OF OBSERVATIONS COLLECTED BY THE COMMITTEE (*continued*).

River, &c.	Observers	Period of Observations
	IN ENGLAND (*continued*).	
[1] Cowm, Clay Lane, and Springmill Reservoirs	Mr. J. Reginald Ashworth, Rochdale	Mar. 1, 1890 (in progress)
Sea at Dover	Capt. J. Gordon McDakin	Feb. 7, 1889 „ „
	II.—IN SCOTLAND.	
Dochart, Lochay, and Loch Tay	Messrs. P. Macnair and J. McRae	Jan. 4, 1888–June 9, 1888
Tummel	Mr. J. Kennedy, Ballinling	Jan. 25, 1888–July 21, 1888
Tay and Braan	Mr. C. Macintosh, Dunkeld	Mar. 17, 1889–June 20, 1890
Almond	Mr. J. Paterson, Almond Bank	Jan. 4, 1888 (in progress)
Tay at Perth	Messrs. Dow, Wilson, and Mechie	Dec. 4, 1886–May 13, 1888
Earn	Mr. J. Ellis, Bridge of Earn	Jan. 18, 1888–June 9, 1888
Thurso at Lochmore, Dale and Thurso	Messrs. J. Gunn, A. Harper, J. B. Johnstone, D. Gunn, D. Campbell, and others	Oct. 15, 1885–Dec. 17, 1888
Forss	Mr. W. Smith, Forss, Caithness	Aug. 2, 1888–Dec. 11, 1888
Wick	Sergeant McKay, Watten	Jan. 16, 1888–April 16, 1888
„	Mr. Simpson, Wick	Jan. 28, 1888–April 16, 1888
Glass	Rev. C. C. McKenzie, Strathglass	Nov. 24, 1888–Mar. 16, 1889
Dee	Mr. J. McKay, Kincardine O'Neill	—
Eden	Mr. F. Peddie, Cupar-Fife	Nov. 30, 1888–Jan. 12, 1889
Aray	Mr. G. Taylor, Inveraray	Jan. 4, 1888 (in progress)
Lochrutton (Kirkcudbright)	Mr. Lindsay	Sept. 13, 1888–Aug. 19, 1889
[2] Nith	Rev. W. Andson, Dumfries	Apl. 15, 1889 (in progress)
[2] Nith Estuary	Mr. Lewis, Kingholm Quay	June 25, 1889–May 31, 1890
[2] Dee (Kirkcudbright)	Rev. W. Ireland Gordon, Tongland	Sept. 9, 1889 (in progress)
[2] Dee Estuary	Mr. Neil McDonald, Little Ross Lighthouse	Aug. 1, 1889–July 31, 1890
Sea at Scrabster (Caithness)	Mr. J. Watson Kerr	Feb. 22, 1888–Mar. 22, 1890
	III.—IN IRELAND.	
Belvedere Lake	Mr. Bayliss, Mullingar	Jan. 1, 1889–Dec. 31, 1889
Sea at Moville	Mr. Lowry	Jan. 14, 1889–June 22, 1890

The periods of observation given above are merely the dates of the first and last observation; in some cases the work was not continuous.

[1] Under the care of the Rochdale Literary and Scientific Society.
[2] Under the care of the Dumfries and Galloway Natural History Society.

Report of the Committee, consisting of Professor G. CAREY FOSTER, Sir WILLIAM THOMSON, Professor AYRTON, Professor J. PERRY, Professor W. G. ADAMS, Lord RAYLEIGH, Dr. O. J. LODGE, Dr. JOHN HOPKINSON, Dr. A. MUIRHEAD, Mr. W. H. PREECE, Mr. HERBERT TAYLOR, Professor EVERETT, Professor SCHUSTER, Dr. J. A. FLEMING, Professor G. F. FITZGERALD, Mr. R. T. GLAZEBROOK (*Secretary*), Professor CHRYSTAL, Mr. H. TOMLINSON, Professor W. GARNETT, Professor J. J. THOMSON, Mr. W. N. SHAW, Mr. J. T. BOTTOMLEY, *and* Mr. T. GRAY, *appointed for the purpose of constructing and issuing Practical Standards for use in Electrical Measurements.*

THE work of testing resistance coils has been continued at the Cavendish Laboratory. A table of values found for the coils is appended :—

Legal Ohms.

No. of Coil	Resistance in Legal Ohms	Temperature
Nalder, 1577 . . . No. 189	·99981	16°·9
Nalder, 1578 . . . No. 190	1·00089	16°·9
Nalder, 1579 . . . No. 191	1·00041	16°·9
Edison Swan, 16 . . No. 192	·99846	13°·9
Elliott, 229 . . . No. 193	1·00028	16°·9
Elliott, 230 . . . No. 194	1·00021	16°·9
Simmons . . . . No. 195	·99992	16°·8
Nalder, 1626 . . . No. 196	1·00045	15°·3
Nalder, 1627 . . . No. 197	1·00056	15°·3
Nalder, 1628 . . . No. 198	1·00058	14°·8
Nalder, 1580 . . . No. 199	1·00072	15°·3

It would be of considerable advantage in the testing if all the coils were made of a uniform size. The original standards of the Association measure $6\frac{3}{4}$ inches from the bottom of the case to the underside of the horizontal portion of the copper connecting-rods, while the vertical portion of these rods is 8 inches in length. These dimensions should be adopted in all coils sent to be tested. If this be done, the baths, &c., made to hold the standards hold the coils equally well, and the additional convenience in testing is very great.

The original standards of the Association have again been several times compared among themselves.

The results of the comparisons appear to show that while the coils A, B, C, D, E, and Flat have remained constant relative to each other; the three platinum silver coils F, G, and H have changed.

The change in F was referred to at the end of the Report in 1888, and is now very large. The coil has increased in resistance by about ·0006 B.A. unit; G, on the other hand, has fallen by about ·0002 B.A. unit, and H by about ·0001 unit. The evidence for these various statements is given in an appendix to the Report by the Secretary.

It is perhaps worth remark that in each case the change either took place during the time that the coil was immersed in ice or was found to have happened when the coil was next measured after its removal from the ice.

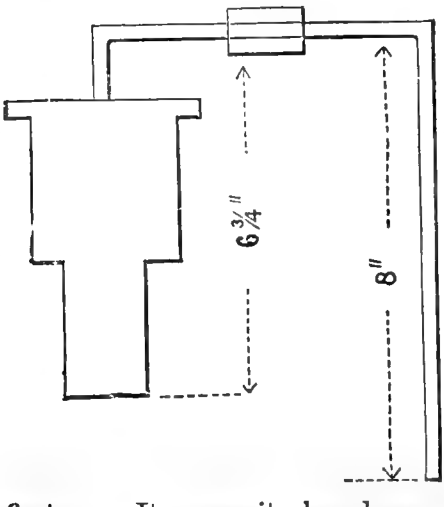
The legal ohm coils have not varied relative to Flat.

The investigations into the resistance of copper have been continued by Mr. Fitzpatrick. The Committee desire again to thank the gentlemen who have rendered him assistance.

Mr. Fitzpatrick has examined various specimens of copper supplied him as wire. He has also examined copper prepared for him as pure by Messrs. Sutton, as well as some which he prepared himself electrolytically from carefully purified copper sulphate. These last two specimens lead to practically the same value as that obtained by Matthiessen for the specific resistance of copper—viz., 1767×10^{-9} B.A. units at 18°; the specific gravity of these specimens is about 8·90. Two wires supplied to him have, however, a distinctly lower resistance: the value for one being 1731×10^{-9}, and for the other 1724×10^{-9}; a difference in the one case of 2 and in the other of 2·4 per cent. The specific gravity of the first of these wires is 8·940 and of the other 8·946, and Mr. Fitzpatrick assigns the increased conductivity to increased density rather than to greater purity.

Matthiessen gives his results for the resistance of copper at 0°. The observations were, however, made mostly at a temperature of 18° or 20°, and reduced to 0° by the use of a temperature coefficient; so that the value at 18° found from that at 0° by the same coefficient will probably represent the result of Matthiessen's work more accurately than the one he gives himself. Various other points of importance are discussed in Mr. Fitzpatrick's appendix. He hopes to be able to give the results for some copper prepared by chemical means by Mr. Skinner and himself. He has also made a number of measurements on silver, but these are not yet complete.

FIG. 1.



Dr. Muirhead and the Secretary have both been working independently at the construction and measurement of a standard air condenser.

Two such condensers have been made for the Committee by the Cambridge Scientific Instrument Company, on a plan suggested by Dr. Muirhead, and mentioned in the last report. The capacity of each of these is about ·02 microfarad. Some slight alterations are required to one of these, the other is completely satisfactory. Its capacity has been repeatedly found, and remains constant to at least within 1 in 2,000, which is about the limit of accuracy attained. Its insulation resistance is good, the loss by leakage being about 1 in 1,000 of the total charge per 1 minute. It has been found possible to compare readily with this standard various mica condensers having capacities of 1, ·5, ·1, and ·05 microfarad. The accuracy of these determinations is about 1 in 2,000. A full account of the construction of the condensers and of the method of making the various tests is given in an appendix by the Secretary, while Dr. Muirhead has contributed some notes on his own condensers and tests.

Another appendix contains an account of a very careful and interesting comparison between the standard mercury thermometers of the Association and a platinum resistance thermometer constructed by Mr. E. H. Griffiths. The resistance thermometer was graduated by means of Regnault's numbers for the vapour pressure of water at various temperatures between 0° and 100°.

The curve of corrections obtained in this way is exactly parallel to that given by the Kew comparisons; there is throughout the range a constant difference of 0°·02 between them. This amount is within the limits of error on the mercury thermometer.

The question of the best value to adopt for the dimensions of a mercury column having a resistance of 1 ohm has been raised by some members of the Committee during the year. There is no doubt that the column of 106 centimetres adopted by the Paris Conference in 1884 is too short.

After a discussion of the results of the most recent observations, the following resolutions were adopted by the Committee:—

1. The Committee recommend for adoption as a standard of resistance sufficiently near to the absolute ohm for practical purposes the resistance of a column of mercury 106·3 cm. in length 1 square mm. in section at a temperature of 0° C.

2. That for the purpose of issuing practical standards of resistance the number ·9866 be adopted as the ratio of the B.A. unit to the ohm.

Thus the new unit may be obtained from the B.A. unit by increasing it in the ratio unity to ·9866; or, to put it differently, the specific resistance of mercury, in B.A. units is taken as $\cdot 9535 \times 10^{-4}$, and the length of a column of mercury which has a resistance of 1 B.A. unit as 104·87 cm. The specific resistance of mercury in ohms is $\cdot 9407 \times 10^{-4}$, while the ohm is 1·0136 B.A. units.

In conclusion, the Committee wish to ask for reappointment, to enable them to continue the work of constructing and issuing standard instruments. Of the grant of 50*l.* made at Newcastle only 12*l.* 17*s.* has been drawn. In order to check any further change in the values of the B.A. units and to render it less necessary to employ the original standards in all the comparisons which are made, it is desirable that the Committee should possess three or four copies of the B.A. unit; while, to enable comparisons to be made between the new air condensers and condensers of capacity comparable with a microfarad, a resistance box going up to several hundred thousand ohms is required.

The Committee are of opinion that they should be in a position to purchase these resistances; they therefore recommend that they be reappointed, with a grant of 100*l.*, that Professor Carey Foster be the Chairman and Mr. R. T. Glazebrook the Secretary.

APPENDIX I.

On the Values of certain Standard Resistance Coils.
By R. T. GLAZEBROOK, *F.R.S.*

THE B.A. UNIT STANDARDS.

The Standard B.A. units of the Association have during the year been several times compared together both by the Secretary and by Mr. Fitzpatrick. Table I. gives the results of two sets of comparisons made in August 1890; the differences between the various coils and the platinum silver standard Flat are given in the third column in bridge-wire divisions. One bridge-wire division is very nearly ·00005 B.A. unit.

TABLE I.—*Resistance of the B.A. Standards, August* 1890.

Coil	Temperature	Difference between each coil and Flat in bridge-wire divisions		Difference observed—calculated	Change of resistance per 1° in b.w.d.
		Observed Aug. 15, 1890	From chart 1888		
A	17·2	27·8	33·0	– 5·2	28·6
B	17·4	30·5	30·5	0·0	28·8
C	17·6	22·2	23·0	– 0·8	14·2
D	17·25	61·2	63·5	– 2·3	61·7
E	17·3	79·2	79·5	– 0·3	60·7
F	17·3	3·2	– 9·5	12·7	5·7
G	17·5	– 22·0	– 18·0	– 4·0	5·5
H	17·4	– 17·0	– 15·0	– 2·0	5·6
		August 19.			
A	18·8	67·5	69·5	– 2·0	28·6
B	17·8	60·6	62·0	– 1·4	28·8
C	19·2	31·6	36·0	4 4	14·2
D	18·8	145·7	15·1	5·3	61·7
E	19·0	170·6	17·3	2·4	60·7
F	18·9	2·9	– 9·5	12·4	5·7
G	19·0	– 21·8	– 18·0	– 3·8	5·5
H	19·0	– 17·7	– 15·0	– 2·7	5·6

In the fourth column are given the corresponding differences obtained from the chart made in 1888. In the next column will be found the differences between the observed values and those given by the chart, while the sixth column gives the change in resistance for 1° C. for the various coils. It will be seen that for the first five coils the differences between observation and the chart are such as would be readily accounted for by a small error in the temperature, and we may say that there is no evidence of a change in the resistance of these coils relative to Flat. This conclusion is borne out by the results of a series of observations made in January and February by Mr. Fitzpatrick. But when we come to the three platinum silver standards, F, G, H, the results are at once seen to be quite different. Thus F would appear to have risen relatively to Flat by about 12·5 bridge-wire divisions, while G and H have fallen by 4 and 2·5 divisions respectively.

Since these are the most important standards, their temperature coefficients being all very small, it was necessary to examine their history with some care. A change in F had been noted in a postscript to the Report for 1888. The general conclusions of that Report were that up to the summer of 1888 there had been no change in the value of the coils. It was shown that all the original platinum silver coils examined then—those of Messrs. Elliott, H. A. Taylor, and others, as well as those belonging to the Committee—had apparently fallen in value relatively to the mean B.A. unit by about ·0007 B.A.U. since 1867, but evidence was adduced to show that the fall was only apparent, due to an error in the temperature coefficient used at that date. A single observation of Chrystal in 1876 pointed to the possibility of a change in F, but that change was not confirmed by other evidence; while so far as the platinum silver coils were concerned, the observations of Dr. Fleming in 1881, and myself in 1888, agreed closely.

Since 1888, however, changes have shown themselves.

These are evidenced by the three following tables II., III., and IV., which give the differences Flat—F, Flat—G and Flat—H respectively.

TABLE II.—*Value of Flat—F.*

Date	Temperature	Value
Chart 1888	10·0 15·0 20·0	10·5 9·5 8·5
May 16, 1888	14·8	9·0
July 2, "	0·0	3·0
July 3, "	14·8	3·8
July 13, "	14·2	4·2
July 13, "	14·6	3·3
July 14, "	14·7	3·3
July 28, "	16·7	4·2
Jan. 1890	10·0	–4·0
May "	14·4	–3·5
Aug. "	16·9	–3·2
Aug. "	16·7	–3·0

TABLE III.—*Value of Flat—G.*

Date	Temperature	Value
Chart 1888	10·0 15·0 20·0	17·5 18·0 18·5
July 1888	14·6	16·6
Jan. 27, 1890	10·0	16·9
Jan. 29, "	4·5	16·7
Feb. 4. "	6·0	16·6
May 31, "	14·4	21·5
June 10, "	16·0	21·4
June 11, "	16·0	22·2
June 12, "	16·0	22·2
June 13, "	16·0	22·2
Aug. 9, "	19·0	21·8
Aug. 15, "	17·0	22·3
Aug. 29, "	16·5	22·6
Aug. 29, "	16·5	22·5

TABLE IV.—*Value of Flat—H.*

Date	Temperature	Value
Chart 1888 . . . . {	10·0	15·5
	15·0	15·5
	20·0	15·5
July 1888	14·6	14·1
Jan. 27, 1890	10·0	17·6
Jan. 29, ,, ...	4·5	17·5
Feb. 4, ,, ...	6·0	16·5
May 31, ,, ...	14·1	18·3
June 10, ,, ...	16·0	18·1
June 11, ,, ...	16·0	17·7
June 12, ,, ...	16·0	16·4
June 13, ,, ...	16·0	16·8
Aug. 9, ,, ...	19·0	17·7
Aug. 15, ,, ...	17·4	17·0
Aug. 28, ,, ...	17·0	17·8
Aug. 29, ,, ...	16·4	18·2

The first three lines in each table give the differences, at the temperature shown, taken from the chart drawn in 1888; the remaining lines give the differences actually observed, with the dates and temperatures. Thus, taking the various coils, it is clear that while up to May 1888 the difference between Flat and F remained the same as shown by the chart and observations up to that date, a change took place during the low-temperature observations in July 1888, while by the time the coils were again examined in January 1890 a further change had manifested itself. This continues up to the present date, so that now at temperature of about 15° the coil F has increased in resistance relatively to Flat by about 12·7 bridge-wire divisions. This, assuming the whole change to be in F, will correspond to a rise of resistance of ·00063 B.A. unit, or in other words the temperature at which the coil is right has fallen by about 2°·3. In January 1890 the coils were again exposed to a low temperature, and it seems probable that the changes took place when the coils were in ice.

From the values in Table III., which gives the values of Flat—G, we see there is no evidence of change till May 1890. The observations in July 1888 and January and February 1890 are quite in accordance with the chart, but in May 1890 it is clear that G has fallen relatively to Flat.

The value of the difference at a temperature of 16° is 22·1 b.w.d. as against 18·1 given by the chart. Thus G has fallen relatively to Flat by 4 b.w.d., or ·0002 B.A. units. This change was first observed after the coils had been exposed to a low temperature.

With regard to H the change first showed itself during the low-temperature observations in January and February 1890, and Table IV. indicates that the difference between Flat and H is now 17·5 divisions as against 15·5 in 1888, or in other words, that G has fallen by ·0001 B.A. unit. Also since Flat—F changed in 1888, while Flat—G and Flat—H did not, we infer that the change at that date was in F, not in Flat; while since Flat—H changed in January 1890 without a change in Flat—G, it appears that the change was in H, not in Flat; and finally, from the observations in May 1890, which show a change in Flat—G, but never in Flat—H and Flat—F, we infer a change in G.

As to the cause of these changes, we can say but little. We hope to investigate them more completely by the aid of the coils lent by Mr. H. A. Taylor and others, and referred to in the 1888 Report; but it seems possible that they are due to strains set up in the wire by the great contractions and expansions produced by cooling and heating in the paraffin in which the coils are embedded. The coil Flat is of a different shape from the others, and little or no paraffin has been used in its construction. The other coils, F, G, H, are embedded in paraffin in the usual way. On cooling down to 0°, this shrinks greatly, and it is quite conceivable that this shrinkage may have strained the coils and so caused the change. We hope to test this by having coils made free from paraffin and investigating with them the effects of repeated heating and cooling. The fall of H and G would be accounted for by a loss of insulation causing a slight leak either from the wire to the case or across the surface of the paraffin. The insulation resistance for F, G, H, was therefore tested and found in each case to be several thousand megohms, while the surface of the paraffin which had become dirty with time was scraped, but without producing any change in the resistance. A leak, of course, would not produce the rise found in F.

Observations of the coils at 0° have always been unsatisfactory and attended with considerable difficulty. This is mainly due, I believe, to the fact that the temperature of the room in which the observations have been made has usually been above zero, and that heat is conducted into the coils by the thick copper connecting-rods. It would seem possible, however, that part of the difficulty (*See* Report of the Committee for 1888, Table VII.) may have been due to real changes in the resistance arising from strains set up by the cooling.

The Legal Ohm Standards.

The results of observations on the legal ohm standards of the Association are given in the Report for 1886. Experiments made on these between July 1884 and January 1886 showed that while one coil, [monogram] 100, had retained its value unchanged, the other, [monogram] 101, had varied. These observations have been continued, and the results are shown in the following tables, which give the value of each coil as found by direct comparison with the standard B.A. units, and its value as given by the chart in 1886.

Table V.—*Results for* [monogram] 100.

Date	Standard used in comparison	Temperature	Value	Value on Chart	Difference
Feb. 1887	F	16·3	1·00009	1·00008	·00001
Nov. 1889	G	15·8	·99997	·99996	·00001
"	"	14·8	·99971	·99968	·00003
"	"	16·0	·99998	1·00000	·00002
Dec. 1889	Flat	14·4	·99962	·99959	·00003
"	"	14·8	·99969	·99968	·00001
"	"	13·2	·99925	·99924	·00001
—	—	6·2	·99744	·99735	·00009
—	—	5·7	·99729	·99720	·00009

TABLE VI.—*Results for* BA 101.

Date	Standard used in comparison	Temperature	Value found	Value on Chart in 1885, 1886	Difference
Feb. 1887	F	16·3	·99970	·99930	·00040
Nov. 1889	G	15·9	·99955	·99920	·00035
"	"	15·1	·99932	·99899	·00033
"	"	16·0	·99955	·99922	·00033
Dec. 1889	Flat	14·4	·99909	·99880	·00029
"	"	15·0	·99925	·99897	·00028
"	"	13·3	·99879	·99850	·00029
—	—	7·6	·99725	·99695	·00030
—	—	6·5	·99701	·99668	·00033

These tables show three facts conclusively: (1) That up to December 1889 no appreciable change had taken place in the relative values of BA 100—the Legal Ohm Standard—and Flat or G; (2) that between January 1886 and February 1887 BA 101, which had varied previously, changed by about ·0004 ohm; and (3) that the greater part of that change has remained permanent up to December 1889. At present the difference between BA 100 and BA 101 is about ·0004; in 1886 it was about ·0008. The agreement between the observations in November and December 1889—in one set of which Flat was the standard of comparison, while in the other G was used—show that the relative change in G and Flat took place after this date.

APPENDIX II.

On the Air Condensers of the British Association. By R. T. GLAZEBROOK (*with a Note by* Dr. A. MUIRHEAD).

The question of issuing certificates of capacity has from time to time been discussed by the Committee. The following paper gives an account of some experiments that have been in progress during the past two years with this object in view.

In the Report for 1887 the Committee express the opinion that it is desirable to proceed with the construction of an air condenser. In conformity with this opinion a meeting was held in London, at which Dr. A. Muirhead exhibited an air condenser consisting of a series of concentric brass cylinders insulated by glass rods, which appeared to the Committee to possess great merits; and it was decided that the Secretary should test this and two similar condensers which Dr. Muirhead offered to lend, before proceeding further with the construction of condensers for the Association. The tests were carried out with satisfactory results.

The capacity of each condenser was determined repeatedly, using the method of a vibrating commutator, due to Maxwell, already employed by J. J. Thomson, 'Phil. Trans.,' 1883, and Glazebrook, 'Phil. Mag.,' August 1884. The values found were:—

$C_1 = ·0030514$ microfarad.
$C_2 = ·0031258$ "
$C_3 = ·0033288$ "

It was found that the capacities remained constant from day to day, and that the accuracy of a single determination was about 1 in 1,000, although the capacity to be measured was so small.

Some mica condensers belonging to the Cavendish Laboratory were compared with these—details of the method will be given shortly—and it was found that when comparing a condenser of 1 microfarad with the three air condensers combined, having thus a capacity of ·009506 microfarad, so that the ratio of the two was about 100 to 1, an accuracy of about 1 in 1,000 was attained. It was also shown that the capacity of the mica condensers as thus found differed by nearly 2 per cent. from their values as determined by the rapid commutator, thus proving that the commutator method was unsuitable for a condenser showing absorption.

Thus for three mica condensers the following values were found :—

With commutator	By slow method of comparison
·9690	·9868
·4934	·4994
·09543	·09644

These results make the necessity for an air standard all the more apparent. A report on the experiments made up to that date was laid before the Committee at a meeting in London in April 1889. It was then decided to adopt Dr. Muirhead's form of condenser, and to have two made on the same pattern for the Association. These have been constructed by the Cambridge Scientific Instrument Company, following Dr. Muirhead's plan, but on an enlarged scale. Each has a capacity of about ·02 microfarad, or about six times that of one of the original condensers.

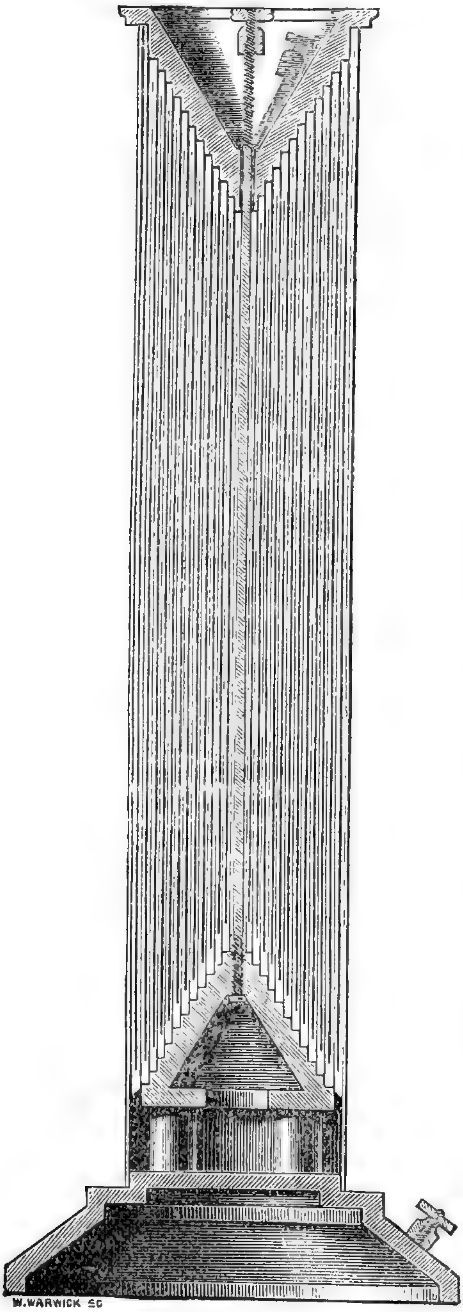
Fig. 2 shows the arrangement.

The condensers consist of twenty-four concentric tubes ; the outer tube is about 2 feet 9 inches high and 6 inches in diameter. Each succeeding tube diminishes in diameter by half an inch ; the tubes are about $\frac{1}{32}$ inch in thickness, and the air space between the inside of one tube and the outside of the next is about $\frac{3}{32}$ inch, but it was found impossible to get all the tubes of exactly the same thickness, so that in some cases the distance between the tubes is less than the above. These tubes are carried by two conical brass castings ; the outside surface of each casting forms a series of twelve steps, over which the successive tubes fit. Each tube is held in position by screws. The upper cone is supported by the outside casing of the condenser, and twelve of the tubes hang vertically from it. The lower cone is carried by three ebonite pillars, about 3 inches in height ; the twelve tubes which are attached to it come respectively between those which are suspended from the upper cone. Thus the insulation depends on the ebonite pillars, assuming there is no leakage across the air from the edges of the tubes. There is an opening in the outer casing, closed by a door, by means of which the ebonite can be cleaned ; the whole is dried by placing inside a small vessel of sulphuric acid. In the centre of the upper cone there is a hole through which a rod passes. The rod is connected with the lower cone, and forms the electrode for the insulated cylinders. An ebonite plug, fitting tightly round the rod, can be pushed down so as to close the hole and prevent the ingress of dust when the condensers are not in use ; when they are being used the plug is removed.

The condensers are placed in the testing room at the Cavendish Laboratory and covered by a wood and canvas case to protect them from dust. It is not intended that they should be movable.

After this description of the condensers we will proceed to an account of the tests to which they have been subject. The first test was for leakage.

FIG. 2.



One set of cylinders was put to the earth while the other was connected with a gold-leaf electroscope. An attempt was then made to charge them with an electrophorus or a small electrical machine, but this failed entirely. The electricity either sparked across at places where the tubes were very close together, or, before the potential rose sufficiently to affect the electroscope, small fibres or dust particles which adhered to the tubes formed leaks across; it was clear that the condenser could not be charged to the potential of the machine. Tests were then applied for leakage when the potential was lower. One set of tubes was connected to one pole of a battery — about thirty-six storage cells were generally employed, having an E.M.F. of 75 volts—the other set being in connection with an insulated key; the second pole of the battery was connected through a galvanometer to the key and the condenser charged. After an interval, usually about five minutes, contact was again made at the key; the deflection of the galvanometer needle—assuming the E.M.F. of the battery not to have changed—was a measure of the quantity of electricity which had leaked from the condensers in the five minutes.

The amount of leakage was very different in the two condensers and depended greatly on the dryness of the air and ebonite pillars. Thus on March 11, when strong acid had been enclosed for some time, for condenser I. the leak per 1 minute amounted to about ·1 per cent. of the whole charge, while with condenser II. it was about ten times as great.

The sulphuric acid was removed during the Easter vacation and replaced by calcium chloride, and after this the leak in I. rose to about 1 per cent. per minute or ten times its former value, while that in II. was from 3 to 4 per cent. of the charge. With the calcium chloride inside the leak was never reduced to less than about ·8 per cent. per minute. In August, the condensers having been closed since June with calcium chloride, there was a leak in I. of about 3 per cent. per minute, while in the same time II. lost about 8 per cent. of its charge.

On August 14, immediately after this test, the calcium chloride was replaced by sulphuric acid, and the leak was quickly reduced to about 1 per cent. per minute for I. For II. no improvement showed itself at once. The next day the leak in I. was about ·4 per cent. per minute; that in II. had not been greatly reduced. On August 16 the ebonite was therefore well cleaned, and air was blown through the tubes of II. and the whole closed for about two hours; the leak had then fallen to about 2 per cent. per minute. By August 18 the leaks were still more reduced, that in I. being ·2 per cent. per minute, while that in II. was ·6 per cent. per minute.

By the afternoon of this day, the upper parts of the condensers having been open to the air of the laboratory for some six hours during other tests, the leaks had appreciably increased, but they had fallen again the next day when the condensers were left closed during the night.

Thus, during the observations in August, with the exception of those on August 14, the condenser I. was losing its charge at the rate of about $\frac{1}{500}$ part per one minute, while the leakage in II. was some five or six times as great, being about $\frac{1}{100}$ part of the charge per one minute.

As will be seen later, several mica condensers were compared with I. and II.; the leaks in them were all small, and did not exceed $\frac{1}{500}$ per minute.

We come now to the experiments for determining the capacities of the two condensers. Of these, three independent series were made, viz. in December 1889, May and June 1890, and August 1890.

The method already referred to was used. Fig. 3 gives a diagram

FIG. 3.

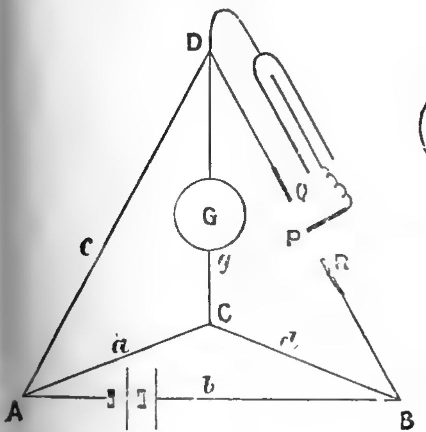
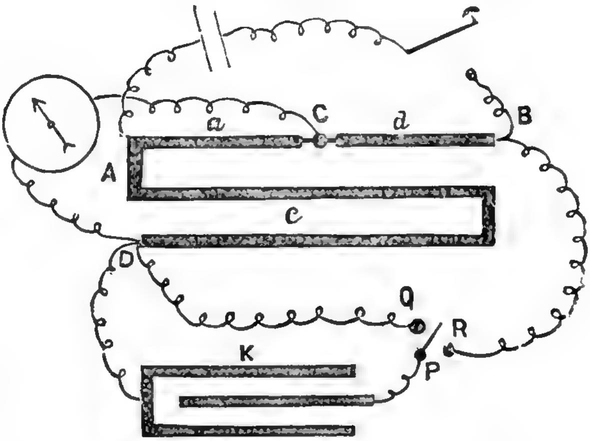


FIG. 4.



of the method; in fig. 4 the connections actually employed are shown. With the notation employed 'Phil. Mag.,' August 1884, we have, if c be the capacity of the condenser, n the number of times it is charged per one second,

$$n\,\mathrm{C}=\frac{a\left\{1-\dfrac{a^2}{(a+c+g)\,(a+b+d)}\right\}}{c\,d\left\{1+\dfrac{a\,b}{c\,(a+b+d)}\right\}\left\{1+\dfrac{a\,g}{d\,(a+c+g)}\right\}}$$

In most of the experiments about to be described, we had the following values in legal ohms:—

$$a=10 \qquad d=\ 1{,}000$$
$$b=18 \qquad g=17{,}600,$$

while c, which was the adjustable arm, varied from 6,000 to 15,000.

With these values, the only correction which need be included is the last factor in the denominator, and we may write

$$n\,\mathrm{C}=\frac{a}{c\,d\left\{1+\dfrac{a\,g}{d\,(a+c+g)}\right\}}$$

The resistances were taken from a legal ohm box belonging to the laboratory; the various coils in this box were carefully compared with each other by Mr. Searle, and found to be consistent with each other, at any rate to within 1 in 10,000. The coils were also compared with the standards of the Association, and it was found that at 16° they were greater than legal ohms in the ratio of 1·0011 to 1. The standard temperature adopted in the experiments was 17°, and since the coefficient of increase of resistance of the box is about ·0003 per 1° C., the resistances require to be multiplied by 1·0014, to reduce them to legal ohms. In some cases, in the value of c, coils from a B.A. unit box, containing coils of ten, twenty, thirty, and forty thousand, B.A. units were employed.

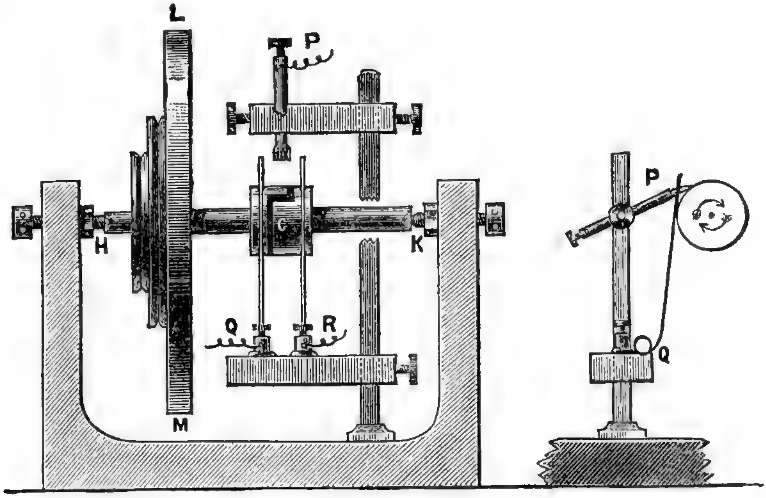
The values found for these coils by myself in terms of the legal ohm box showed that they were very consistent with each other, and that the nominal 10,000 B.A.U. was equal to 9,880 legal ohms as measured by the legal ohm box.

In the comparisons of two condensers certain coils from a megohm box were used; the value of each of these was also determined. They were as follows:—

1	...	98,731	Legal ohms of standard box.
2	...	98,625	" "
3	...	98,698	" "
4	...	98,735	" "
9	...	98,725	" "
10	...	98,776	" "

In the experiments on Dr. Muirhead's condensers, the vibrating commutator described in Professor Thomson's paper, 'Phil. Trans.,' 1883, or in my paper, 'Phil. Mag.,' 1884, was used, and that with complete success. In the experiments about to be described, this was replaced by a rotating commutator which had been fitted up by Professor Thomson and Mr. Searle for their experiments on the other value of 'v,' and which possesses certain advantages over the other form. Dr. Muirhead and Dr. Fleming have also used a somewhat similar arrangement of apparatus. Fig. 5 shows the arrangement. The split ring commutator is carried on the axle H K, which is driven by a water motor. Two wire springs, Q, R, are in contact with the two halves of the commutator respectively, and as it rotates the brush P, made of very fine brass wire, is brought into communication alternately with Q and R. The disc L M was of iron, and its mass helped to steady the motion. On one face of the disc a series of circles were drawn forming a number of annuli. The

FIG. 5.



successive annuli were divided each into a different number of divisions by radial marks. Thus in the innermost annulus there were four, on the next five, and so on. The disc as it rotated was watched in the usual stroboscopic manner through two slits on two pieces of thin metal carried by the prongs of a tuning-fork, which made about 64 vibrations per second.

When the frequencies of the disc and of the fork were in certain simple ratios to each other, the corresponding pattern on the disc was seen in a steady position. The driving pulley of the motor carried a second band, which passed over an idle pulley near the observer at the tuning-fork, and the speed of the motor, and hence of the disc, was adjusted partly by varying the flow of water, partly by friction on this band, until the desired pattern was seen in the steady position. This position was easily maintained by varying the friction on the string. The tuning-fork drove a second fork an octave above itself in frequency. This fork was mounted near the standard fork of the laboratory, and the beats between the two were counted. The frequency of the standard fork was determined by Professor Thomson and Mr. Searle for their experiments on '*v*,' recently communicated to the Royal Society. They found that it had changed slightly since it was determined by Lord Rayleigh, and give as the result of their experiments

$$\text{Frequency at temperature } t^\circ = 128{\cdot}105\{1-(t-16){\cdot}00011\}.$$

The driven fork was always adjusted to a slightly lower frequency than that of the standard, so that there were about 20 beats to the minute between the two. During each series of observations the beats were repeatedly counted, but they rarely varied during the series sufficiently to affect the result. The commutator was designed and partly constructed by Mr. Searle, who observed at the tuning-fork throughout. A little attention was required to secure good contact between the springs Q, R and the rotating parts, and also to adjust the brush P, but with moderate care in the adjustments the apparatus worked perfectly.

The galvanometer was one constructed in the laboratory; it had a resistance of 17,600 ohms, with a long silk fibre suspension—a quartz fibre would have been an improvement.

Its sensitiveness was such that 1 scale division corresponded to $\cdot 83 \times 10^{-10}$ C.G.S. units of current; the time of swing was 7·2 seconds, so that the sudden discharge through the galvanometer of 10^{-10} C.G.S. units of electricity produced a throw of 1 division; or, in other words, the quantity which, when discharged suddenly through, gave a throw of γ divisions was $\gamma \times 10^{-10}$. This was determined by discharging through the galvanometer a condenser of capacity ·1 microfarad; when charged to 1 volt, the throw observed was 100 divisions, while the steady current due to an E.M.F. of ·001 volt produced a deflection of 72 divisions.

The observations were made by varying c. There was a commutator in the battery circuit. In each position of this commutator two values of c were taken and the corresponding resting points of the spot on the scale observed. From these the value of c, which corresponded to the zero position of the spot, was obtained by interpolation.

These observations were made twice for each position of the commutator, and the mean taken.

We will give one series as an example:—

August 27, 1890.—Temperature of standard fork, 18°·8.
" " Beats " " 20 in 65·4 seconds.
" " " " " 20 in 65·2 "

Condenser No. 1.

Frequency, 80 approximately.

Position of Commutator	Zero Reading	Resistance	Resting Point
/	48	5890 5880	47 51
\	48	5880 5890	46 49
/	48	5890 5880	48 51
\	49	5880 5890	46 50

Temperature of coils, 17°·5. Beats, 20 in 64·8 secs. at 19°·3.

It will be seen that between the third and fourth series the galvanometer zero has shifted slightly.

From these we get as the four values of c the following:—

5887·5
5886·6
5888·3
5887·5

Mean, 5887·5 at 17·5
Correction to 17°, ·9
Value of $c =$ 5888·4 at 17°,

while the beats are 20 in 65 seconds at 19°, or ·307 per 1 second; at 19° the frequency of the standard is 128·066; thus the frequency of the driven fork is 128·066 − ·307, *i.e.*, 127·759. Thus for the driving fork we have the octave below this, or 63·879, while the frequency of the commutator is 5/4 of this.

Hence in this series :

$$n=79\cdot849, \qquad c=5888\cdot4.$$

The accuracy attained in this series is a fair specimen of the whole. With these explanations we proceed to give the results in tabular form, showing the date, the values of n and c, and the resulting value of C. The wire by which the condenser was connected to the commutator, together with the commutator itself, had a certain capacity which was determined in the same way, merely disconnecting the wire from the condenser. In the observations in December and June we found—

$$a=10 \quad d=98730 \quad c=28460 \quad n=63\cdot9,$$

whence the capacity of the wires is ·0000625 microfarad, while in August, after the apparatus had been set up afresh in a different position with new connecting wires, the value of c was 22,200 and the capacity ·0000799 microfarad; for the wires the values of c could be determined to about 1 per cent.

In the table the value of C has been corrected for the capacity of the wires.

TABLE I.—*Condenser I.*

Date	Value of c	Value of n	C, in microfarads	Mean of Series
December 31, 1889	14762·5 7372·3 5894·3	31·95 63·90 79·875	·021025 ·021016 ·021019	·021020
May 20, 1890	14772·9 7376·5 5896·4	31·93 63·86 79·825	·021023 ·021017 ·021025	·021022
June 16, 1890	7375·0	63·86	·021022	·021022
August 27, 1890	14745·9 7364·8 5888·4	31·939 63·879 79·849	·021038 ·021027 ·021030	·021032

Mean of the whole, ·**021024** microfarad.

TABLE II.—*Condenser II.*

Date	Value of c	Value of n	C, in microfarads	Mean of Series
December 31, 1889	13957·4 6963·6 5575·1	31·95 63·90 79·875	·022238 ·022249 ·022225	·022237
May 20, 1890	13945·3 6957·4 5568·2	31·93 63·86 79·825	·022271 ·022283 ·022266	·022273
June 16, 1890	6953·4	63·86	·022296	·022296
August 27, 1890	13774·6 6878·6 5500·4	31·939 63·879 79·849	·022523 ·022515 ·022518	·022519
August 28, 1890	6878·6	63·881	·022515	·022515

TABLE III.—*Giving the Capacity of two Mica Condensers for various Frequencies of Charge.*

Frequency	June 12	June 14	June 16	Mean
		CONDENSER A.		
21	·04885	·04886	—	·04886
32	·04883	·04884	—	·04884
64	·04868	·04868	·04864	·04867
80	—	·04859	—	·04859
		CONDENSER B.		
21	—	·09642	—	·09642
32	—	·09642	—	·09642
64	—	·09634	·09642	·09638

Taking the air condensers first, the tables show that, at any rate for frequencies between 32 and 80 per second, the time of charging has no effect on the capacity, while the individual observations in each series are within 1 in 2,000 of each other.

For condenser I. the observations at frequency 64 are in all the series the least, but this is not the case with condenser II.

The capacity of condenser I. shows no change between December 1889 and June 1890. The observations in August 1890 are all rather greater than those in the earlier series, but the increase, about 1 in 2,000, is almost within the error of the experiments. With regard to condenser II. there is an indication of a rise in its capacity all through. It will be remembered that we have already shown that the insulation resistance of II. is considerably less than that of I., but it is easy to see that this leak was not sufficient to account for the change, for if R be the resistance of the leak then our approximate formula becomes

$$n\text{C}+\frac{1}{\text{R}}=\frac{a}{cd}, \text{ instead of } n\text{C}=\frac{a}{cd}.$$

Now, the current through the condenser when leaking most was about ·0002 E C, where E is the E.M.F. to which it is charged and C the capacity of the condenser.

Thus the resistance of the leak is $\frac{1}{\cdot 0002 \times \text{C}}$, or $\cdot 25 \times 10^{21}$ C.G.S. units, since the value of C is $\cdot 02 \times 10^{-15}$. This resistance is 250,000 megohms.

Hence the correction to the capacity $=1/n\text{R}=\cdot 0002 \times \text{C}/n$, and this is far too small to affect the result.

There is no doubt, then, that the capacity of II. altered during the experiments by about 1 per cent., and it will be necessary to take it to pieces and set it up again.

It will be remembered that in the early part of August the leak in II. was very great, and it seems probable that the steps taken to discover the cause of the leak have produced a change in capacity. The experiments on II., then, serve merely to show that the capacity can be found by the rotating commutator method to a high degree of accuracy, while those on I. prove that an air condenser, of ·02 microfarad capacity, has been constructed which has retained its capacity unaltered for the eight months between December 1889 and August 1890.

The values of c are given in terms of the coils of the legal ohm box at 17°. Hence the capacity found needs to be divided by 1·0014 to reduce it to legal microfarads, and it then becomes ·020995.

Moreover, since 1 legal ohm=1·01124 B.A.U., and 1 B.A.U.=·9866 $\times 10^9$ cm. per sec., we have

$$1 \text{ legal ohm} = \cdot 9977 \times 10^9 \text{ cm. per 1 sec.}$$

And the absolute electro-magnetic measure of the capacity of the condenser I. is

$$\mathbf{\cdot 021043} \times 10^{-15} \text{ sec.}^2 \text{ cm.}^{-1}.$$

The effect of the leak in condenser II. was still further investigated on August 28. The plates of II. were connected by a resistance of 30 megohms. Hence the correction to C, which is

$$-\frac{1}{n\text{R}} \text{ becomes } -\cdot 000520 \times 10^{-15}, \text{ when } n=64.$$

The value of C found with the leak in was $\cdot 023813 \times 10^{-15}$.

Hence making the correction C=·02249 microfarad, which is sufficiently close to the value found without the artificial leak.

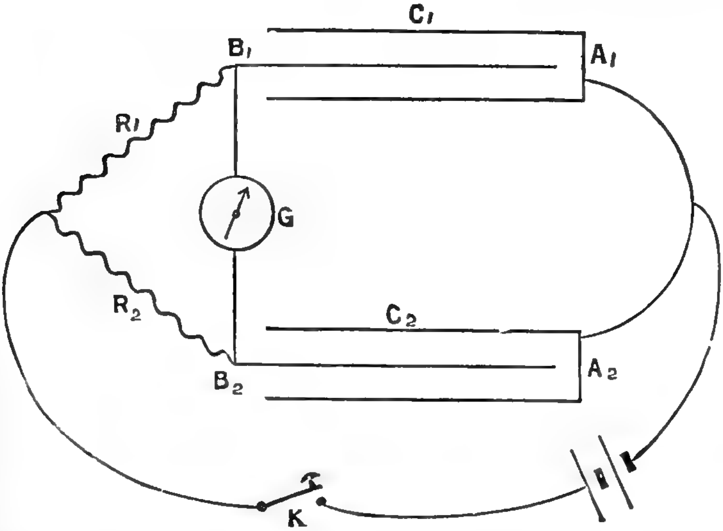
Table III. shows that with mica condensers not very much greater in separate capacity than the air condensers a change in the frequency of the charge from 21 to 80 produces an appreciable change in the capacity. This, of course, is in consequence of the absorption. With large condensers, as we have already seen, the effect is more marked.

It remains, then, to give an account of the experiments undertaken for the purpose of comparing mica or paraffin condensers as ordinarily used with the air condensers, and of investigating some of the effects of absorption.

The two well-known methods of De Sauty and Sir William Thomson have both been employed.

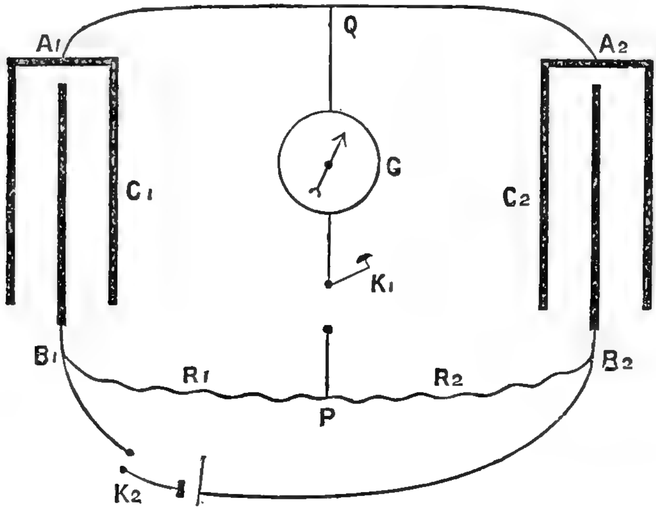
The arrangements are shown in Figs. 6 and 7.

FIG. 6.



The first of these is not really suitable for use in cases in which there is absorption, though, with care, a fairly accurate measure of the instan taneous capacity can be found. The resistances R_1 R_2 can always be arranged so that the effect of the charge rushing into the air condenser shows itself as a sharp kick of the spot of light—to the left, say—followed

FIG. 7.



by a slower deflection in the other direction, due to the absorption charge soaking into the mica or paraffin. The resistance for which this sharp kick practically disappears is fairly definite, and from it the instantaneous capacity can be found, while an observation of the resulting kick due to the absorption enables us to calculate the increase of capacity which arises from that cause. This can be done in various ways. The simplest, perhaps, is to disconnect the condensers from the circuit, and, replacing the mica condenser by a variable condenser of small capacity, observe the kick this produces in the galvanometer when charged with the same battery. From this the capacity to which the absorption is equivalent can be approximately calculated.

Thus a condenser of about ·1 microfarad was compared with Dr. Muirhead's three condensers combined. Taking C_2, R_2 to refer to the air condenser, we had

$$C_2 = \cdot 009506$$
$$R_2 = 898650 \text{ ohms};$$

and with $R_1 = 89300$ there was a slight tremor to the left and a movement of three divisions to the right. On changing R_1 by 100 ohms the change in the motion of the spot was marked.

This gives for the instantaneous capacity $C_1 = \cdot 09550$; the value found by the commutator at frequency 64 was ·09543 microfarad.

To evaluate the five divisions the air condenser was disconnected and the mica condenser replaced by one of capacity ·001 microfarad; the kick observed was 4·8 divisions, while with ·002 microfarad it was 9 divisions. Thus a kick of 5 divisions corresponds to about ·0011 microfarad capacity. Hence the capacity of the mica condenser, including the full effect of absorption, is ·0966 microfarad.

The second method, about to be described, in which the absorption effect is included, gave ·0965 microfarad.

Let us now consider the second method. The current from a battery flows through B_1 P B_2 (Fig. 7), a large resistance of amount R_1+R_2. One plate of each condenser is in contact with B_1 and B_2 respectively; let V_1, V_2 be the potentials at these points. The other plates A_1, A_2 are insulated and connected together and to the galvanometer G; the other pole of the galvanometer can be connected to P through the insulated key K_1. The galvanometer can be replaced by an electrometer. Let R_1 be the resistance P B_1; R_2 the resistance P B_2. Suppose the point P be put to earth, the rest of the circuit being insulated; then if C_1 C_2 be the capacities, it is easy to see that there will be no current through the galvanometer on making the key K_1, if $C_1 R_1 = C_2 R_2$.

Now, in the case of a mica or paraffin condenser the capacity is a function of the immediate past history of the condenser, and different values will be found for the resistances R_1, R_2, according to the time the charging has lasted. Dr. Muirhead, however, who uses the method largely, has shown how to obtain the instantaneous capacity from the observations. His method is described in the following extract from a letter to myself.[1] In the method as described one pole of the battery is to earth instead of the point P of Fig. 7.

Dr. Muirhead writes: 'I have ·05 microfarad nearly in air condensers, and a series of mica condensers of ·1, ·2, ·3, ·331 (original 1/3), and ·498

FIG. 8.

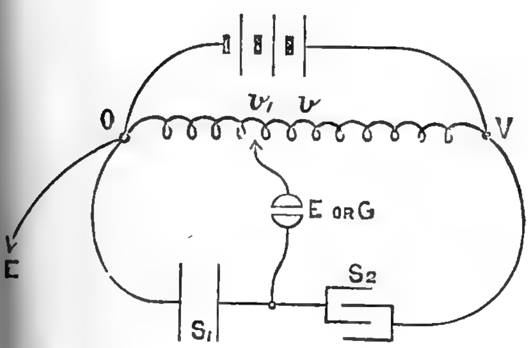
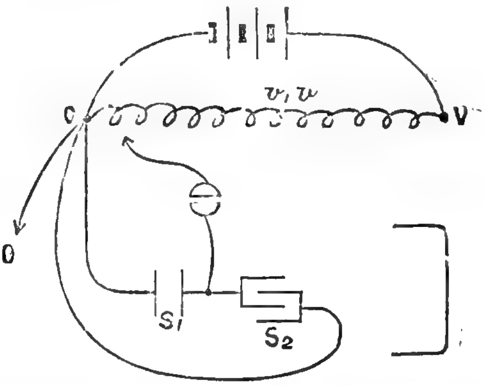


FIG. 9.



(original ·5) mf. capacity, all enclosed in a double air-tight box, to keep the temperature as uniform as possible. The capacity of these standards is determined periodically by both the tuning-fork method (using a revolving commutator instead of the tuning-fork) and by the ballistic galvanometer method. One can make comparisons of these condensers among themselves, and with other condensers by the method I adopt, to an accuracy of 4 in 10,000. The temperature coefficient of shellacked mica condensers is about ·018 per degree Centigrade, and of paraffined mica ·034 per cent.

'Let S_1 be the capacity of the air condensers;
" S_2 " " condenser to be compared with air condensers.

'After making battery contact, supposing the charging of the condensers to be instantaneous and the absorption *nil*, then we have

$$v\, S_1 = (V - v)\, S_2$$

[1] See also *Electrician*, September 5, 1890.

where v is the potential of the junction of the two condensers. Should there be any delay in obtaining the balance, the position of v on the slides will vary—say to v_1; then the charges on the two condensers will be

$$v_1 \mathrm{S}_1 \text{ and } (\mathrm{V}-v_1)(\mathrm{S}_2+\sigma)$$

respectively, where σ is the apparent increase of capacity of S_2 due to absorption or soaking in of charge. On disconnecting the armature of S_2 from the slides and putting it to earth, the potential falls from V to O, and immediately afterwards the potential of the junction of the two condensers becomes, say, v_2, so that

$$\mathrm{S}_1 v_1+\mathrm{S}_2(v_1-\mathrm{V})=(\mathrm{S}_1+\mathrm{S}_2)v_2$$

Hence

$$v_1(\mathrm{S}_1+\mathrm{S}_2)-\mathrm{V}\,\mathrm{S}_2=(\mathrm{S}_1+\mathrm{S}_2)v_2$$

or

$$\mathrm{S}_2=\mathrm{S}_1.\frac{v_1-v_2}{\mathrm{V}-(v_1-v_2)}$$

V and v_1 are known, and v_2 is indicated at once on an electrometer; or when a galvanometer is used it can be measured quickly thus:—As soon as v_1 has been observed, break the galvanometer contact and move the index of the slides down to O; then directly after bringing the armature of S_2 from the full potential of the slides to zero, close the galvanometer circuit and observe the throw, a, which is a measure of v_2, the potential of the junction of the two condensers.'

In my own experiments, which were made after consultation with Dr. Muirhead, I adopted a method practically the same as his; but before describing it, it will be better to consider rather more the effects of absorption. Let us suppose, at first, that the leakage from either condenser is inappreciable. If there be no absorption, each condenser is charged to its full potential practically instantaneously; and it does not matter when or in what order the keys, K_1, K_2, are put down, the position of P on the slide is not affected.

Suppose now that C_1 shows absorption, the capacity increases with the time of charging. We can get the instantaneous capacity by depressing, first, the key K_1 and then K_2, but in this case we are troubled with the effect of the slow after charging as in the other method. Still the resistance, for which the kick due to the initial charging is zero, is, with the condensers I employed, fairly marked, and a value for the instantaneous capacity can be thus fairly accurately obtained.

If, now, K_2 be made for 1 second and then K_1 depressed, a different position will be found for P. With this interval of charge the apparent capacity differs appreciably from its instantaneous value, and the after-effects of the absorption can still be observed. The same is true for intervals of 2, 3, or 4 seconds—the value obtained for the capacity increases, and the after-effect is still noticeable; but with the condensers and battery I used, if the time of charging was prolonged to 5 seconds, the after-effect was inappreciable, and the position of P on the slide, and hence the apparent value of the capacity, was hardly affected by further increasing the time of charge. In the experiments on a cable recorded in Dr. Muirhead's paper already referred to, the absorption effects continue much longer. In the observations recorded below, then, unless the contrary is stated, the key K_2 was held down for 5 seconds, and then, K_1 being depressed, the position of P determined, for which the galvanometer remained unaffected. The value of the capacity deduced then is the full capacity for the potential to which the condenser is charged. It is of course possible, though further experiments would be wanted to prove it, that the full effect of absorption is not merely to increase by a definite amount, independent of the potential, the apparent instantaneous capacity, but that the increase may depend on the potential to which in each case the condenser is being charged. It will of course depend on the purposes for which the condenser is to be used whether the instantaneous capacity or the full capacity is required, and it probably will be best, when issuing certificates, to state both the instantaneous capacity and the maximum increase due to absorption—mentioning at the same time the difference of potential used in the experiments for determining this correction, and also the time of charging in which this maximum increase is practically attained.

The method I employed in determining the correction due to absorption was the following:—Suppose the plates, A_1, A_2, to be at potential zero and uncharged. Make the battery key, K_2, and after keeping it made for some little time break it again. If there be no absorption A_1 and A_2 will still be at zero potential and uncharged; but let there be absorption in one of the two, A_1, and let B_1 be the positive pole of the battery, then, while the battery is on, negative electricity is being absorbed by the dielectric near A_1, and positive electricity is left free over the plates, A_1, A_2, and the wires connecting them. When the battery is broken the negative electricity begins to soak out, but the process takes time. Hence, if immediately on breaking the battery key, K_2, the galvanometer key, K_1, is made for an instant, there is a throw of the galvanometer needle indicating the passage to the earth of the positive set free by the absorption. If, after a time, the galvanometer key be again depressed, there is an equal throw in the opposite direction, caused by the passage of the negative electricity which has again soaked out of the condenser. The required correction is obtained from either of these throws.

For, let i be the current between B_1 and B_2; let C_1 be the instantaneous capacity of the one condenser and C_2 of the other; and let Q be the quantity of electricity absorbed. Then the quantity of negative electricity on the plate A_1 is $C_1 R_1 i + Q$, and the quantity of positive electricity on the plate A_2 is $C_2 R_2 i$, if we assume the potential of these plates to be still zero.

Therefore,

$$C_1 R_1 i + Q = C_2 R_2 i$$

$$\therefore \frac{C_1}{C_2} = \frac{R_2}{R_1} - \frac{Q}{C_2 R_1 i}$$

Then, neglecting the battery resistance, if E be the E.M.F. of the battery,

$$i = \frac{E}{R_1 + R_2}$$

$$\therefore \frac{C_1}{C_2} = \frac{R_2}{R_1} - \frac{Q}{C_2 E}\left(1 + \frac{R_2}{R_1}\right)$$

Now, we have seen that with the galvanometer as I used it, if γ is the throw produced by the passage of a quantity Q, then $Q=\gamma\times10^{-10}$.

The battery consisted of 36 small storage cells, which, when fully charged, had an E.M.F. of about 75 volts, so that

$$E=75\times10^{8}.$$

Also,
$$C_2=\cdot021 \text{ microfarad}$$
$$=21\times10^{-18}.$$

Hence, with these numbers,

$$\frac{C_1}{C_2}=\frac{R_2}{R_1}-\frac{\gamma}{1575}\left(1+\frac{R_2}{R_1}\right)$$

or, writing it as a correction to C_1,

$$C_1=\frac{C_2\ R_2}{R_1}-\frac{\gamma}{75}\left(1+\frac{R_2}{R_1}\right)10^{-18}.$$

Examples of the method of applying this correction will be given shortly.

It will be noticed that a leak in one of the condensers may be corrected for in the same way. For, suppose the mica condenser to leak, then a quantity Q' of positive electricity passes through to the plate A_1, while the battery current is on, and the condition that the galvanometer should not be deflected is,

$$C_2\ R_2\ i-C_1\ R_1\ i=Q'$$

the same equation as previously.

There will, however, be this difference: on depressing the key K after breaking the battery circuit, a positive charge will in both cases pass from A to B through the galvanometer; if this charge be due to absorption, there will, when the key is again depressed after an interval, be a current through the galvanometer in the opposite direction; while if the first charge be due entirely to a leak, there will be no effect when the key is the second time depressed. In practice, the leak and the absorption may exist together either in the same or different condensers. In the second case the leak will tend to produce opposite effects to those caused by the absorption; the quantity Q', however, increases nearly in the ratio of the time of charging, while Q increases for the first few seconds, but soon reaches a maximum and then remains constant.

These considerations are illustrated by some experiments in which the condensers I. and II. were compared with various mica condensers. The battery key was in each case made for 30 seconds; it was then broken, and the galvanometer key was made for an instant. The resulting throw was the sum of those due to (1) the leak in the mica condenser, (γ), say; (2) the absorption in that condenser, (α), say; and (3) the leak in the air condenser, which produces an effect in the opposite direction ($-\gamma^1$), say.

After about 30 seconds more the key was again depressed; the resulting throw is due to the absorbed electricity which has again leaked out, and will give us $-\alpha$.

The following table gives the results; each observation entered is the mean of three or four.

Condenser compared with Standard	—	I.	II.
·05	$\lambda+\alpha-\lambda^1$ $-\alpha$	2·3 −3	−7·3 −2·6
·1	$\lambda+\alpha-\lambda^1$ $-\alpha$	2·2 −3	−9 −3
·1	$\lambda+\alpha-\lambda^1$ $-\alpha$	2·2 −2·2	−7 −3·5
·5	$\lambda+\alpha-\lambda^1$ $-\alpha$	3·3 −3·3	−4 −2·5
·1	$\lambda+\alpha-\lambda^1$ $-\alpha$	4 −5	−3·2 −5·7

If we take the comparisons with condenser I. first, it appears that throughout $\lambda-\lambda^1$ is small. For the ·05 and ·1 microfarad it may be about −·5 division, while α is about 3 divisions; for the ·5 microfarad, α is rather larger, being about 3·3, and $\lambda-\lambda^1$ is zero, while for the 1 microfarad α the absorption effect is distinctly larger, being 5 divisions, and $\lambda-\lambda^1$ is about −1. All this is, of course, quite consistent with the fact that condenser I. and the mica condensers insulate well while there is absorption by the mica.

When, however, we come to the condenser II. the results are quite different. While the absorption effects are comparable, as of course they ought to be, with those obtained in the comparison with I., the leakage effects are very large.

The values of $\lambda-\lambda^1$ in order are as follows: −9, −12, −10·5, −6·5, −8. Now, we know that the mica condenser shows very little leak effect; the above leaks are therefore almost entirely in the air condenser II. If we suppose the total leak to be proportional to the time, then for the 5 second charges used in the experiments the corresponding values of γ in the corrections to be introduced for leakage will be one-sixth of the above, and thus we get the following results:—

Condensers	Value of γ	Correction for the Leak to Capacity in Microfarads	Condensers	Value of γ	Correction for the Leak to Capacity in Microfarads
·05	1·5	·00007	·5	1	·0003
·1	2	·00016	1·5	1	·0007

It is clear that the corrections are in all cases small, being not much over 1 in 1,000, but they serve to illustrate the method. The above corrections are only those for the leak; the correction for absorption could be found in the same way.

With a view to testing the method in a case in which a leak only existed without absorption, a number of comparisons of I. and II. were made.

In these experiments the resistance with I. was 296,240. The resistances with II., and the deflections due to the leak obtained by breaking the battery and then making the galvanometer, are given below, together with the ratio of the two capacities corrected for the leak.

Interval between Battery and Galvanometer Contacts	Resistance	Leak in Scale Divisions	$\frac{R_1}{R_2}$	Correction	$\frac{C_2}{C_1}$
0 seconds	275,980	0	1·0734	0	1·0734
5 "	275,180	2·5	1·0765	−·0032	1·0733
30 "	271 380	14·5	1·0916	−·0184	1·0732
60 "	267,180	22·5	1·1088	−·0286	1·0802
5 "	91,370	5	4·3223	·0168	4·3391
30 "	92,670	22	4·2617	·0743	4·3360
60 "	94,170	42	4·1938	·1415	4·3353

The last three lines of the table give the results of a series of comparisons between II., which had a leak, and a condenser of ·1 microfarad, which showed absorption. The resistance with II. was 394,930 ohms.

In the first four lines the corrections are negative, for the capacity of the leaky condenser is being found in terms of the standard. In the next three lines they are positive, for the ratio of the mica condenser to the leaky standard II. is being found.

A comparison of the fourth and sixth columns shows the results of the correction. In the fourth line it is clear that the correction is not large enough. This probably arises from the difficulty of making contact with the galvanometer circuit sufficiently soon after the battery is broken to insure that the whole of the charge accumulated by the leak should pass through the galvanometer.

The leak correction was also tested with similar results by putting an artificial leak in I.

We will now give some specimens of the observations made to compare I. with a mica condenser in order to show the accuracy attained. Condenser I. compared with ·1 microfarad; resistance with I., 493,560 ohms; resistance with ·1 microfarad, 105,800 + a variable resistance given below.

In the table in which the effect of the galvanometer is shown by the letters R, L, in the last column, R means there was a deflection to the right, L to the left.

Interval between Galvanometer and Battery Contact	Variable Resistance to be added above	Effect on Galvanometer
5 seconds	700	R
	400	L
	500	very small R
2 "	400	L
	700	R
	600	L
0 "	1200	L
	1300	Tremor L, then swing to R
	1400	R

Thus in this case the effect of an alteration of 100 in the resistance, *i.e.* $\frac{1}{1000}$ of the whole, is very marked, and we may take the following values for R:—

5 seconds interval	105,800 + 500
2 " "	105,800 + 650
0 " "	105,800 + 1300

Other series of observations showed that the resistance for 10 seconds' interval was the same as for 5 seconds'; if the interval was prolonged to 30 seconds a very small increase in capacity was noticeable. Thus the effect of absorption is to increase the capacity of the ·1 microfarad by about 8 in 1,000, or ·008 of the whole; of this ·0065 shows itself in the first 2 seconds of charging and ·0015 afterwards, the increase after 5 seconds, if any, being extremely small.

When comparing I. with ·5 microfarad the resistances used were 592,290 and 24,900 respectively. In this case an alteration in the latter resistance of 10 ohms, or $\frac{1}{2500}$, was easily seen. The following are the results:—

Interval	Resistance	Interval	Resistance
10 seconds	24,900	2 seconds	24,930
5 "	24,900	0 "	25,060

These again show that the absorption effect disappears after 5 seconds, and that the effect of absorption in 2 seconds is about ·0052, and in 5 seconds about ·0064 of the whole capacity.

When comparing with 1 microfarad, the resistances were 592,290 and 12,580, the last number being accurate to about 5 ohms, or about the same proportion as before.

The results of the various observations are given in the following table; the observations made with II. have been corrected for the leak, as already explained.

Table giving the Capacities of certain Mica Condensers as compared with the Air Condensers.

Date	Value from I.	Value from II.	Value found by Commutator at frequency 64
August 19 . .	·04934	·04938	·04867
" 23 . .	·04934	·04936	
June 17 . .	·09772	·09780	·09638
August 14 . .	·09751	—	
" 18 . .	·09773	·09786	
" 21 . .	·09773	·09781	
August 18 (M) .	·5005	·5008	
" 18 (A) .	·5007	·5009	
" 21 . .	·5006	·5010	
August 18 . .	·9910	·9912	
" 21 . .	·9913	·9912	

It will be noticed that, for either condenser I. or II., the results are in very close accordance; with the exception of one observation, on August 14, the differences are barely as great as 1 in 5,000, and the method is clearly capable of giving the value of a mica condenser, in terms of the air condenser, to this accuracy.

The reason for the low result on August 14 is to be found in the fact that on that day the leak was considerable, being, as we have seen, over 1 per cent. per minute. Full observations for the correction were not taken; it would, however, amount to about ·0002, judged by the correction required to observations on II., when leaking at a similar rate.

The results from II. are equally consistent among themselves, but all slightly greater than those from I. This would indicate that the correction applied for the leak in II. is rather too large.

The capacities given in the table are those found with a 5 seconds' interval, by which time, as we have seen, the absorption on the mica condensers used is practically complete. We have already discussed the method of determining the instantaneous capacity, and a table of the corresponding values could easily be given.

For our present purpose it is hardly necessary to do this, and indeed for many purposes for which condensers are employed a knowledge of the full capacity is more useful than one of the instantaneous one. In the last column the values of the capacities found by the commutator method are given; the differences in both cases amount to about 1·3 per cent. of the capacity.

During the forthcoming year condenser II. will be again set up and tested, and the permanent arrangements for rapidly comparing condensers and for issuing certificates will, I hope, be completed.

APPENDIX III.

On the Specific Resistance of Copper. *By* T. C. FITZPATRICK.

All the values given in tables for the specific resistance of the metals are directly or indirectly obtained from the values given by Matthiessen in his series of papers published in the 'Transactions of the Royal Society' for the years 1860–1864, and in the Reports of the British Association for the same years.

In the 'Transactions'[1] for the year 1860 is a paper by Matthiessen on the conductivity of pure copper, and on the effects of impurities on it; no alloy of copper having as high a conductivity as the pure metal. His results are expressed in terms of the conductivity of a hard-drawn silver wire (100 at 0°). He gives the following values for samples of copper carefully prepared by himself:—

(1) 93·00 at 18°·6		Giving a mean value of 93·08 at 18°·9 as the conductivity of pure copper.
(2) 93·46 ,, 20°·2		
(3) 93·02 ,, 18°·4		
(4) 92·76 ,, 19°·3		
(5) 92·99 ,, 17°·5		

Numbers are given showing the effect on the conductivity of small quantities of oxide, and he states that he found it necessary to pass hydrogen through the molten metal for some time for entire reduction. In the 'Transactions' for 1862 Dr. Matthiessen has a paper on the influence of temperature on the conductivity of metals. He again expresses his results in terms of a hard-drawn silver wire. On page 8 of that paper will be found the results of his experiments on copper: the lowest temperature at which measurements were made was 12° or

[1] *Phil. Trans.* 1860, p. 85.

16°; he there shows how the results for pure copper measured at 18° may be reduced to 0° C.; but no measurement was actually made at 0° for any of the metals experimented with.

He expresses the influence of temperature on a hard-drawn copper wire, the mean result of a number of determinations, by the equation

$$\lambda = 100 - \cdot 38701t + \cdot 0009009t^2$$

where 100 is the conductivity of copper at 0° C., so that a hard-drawn silver and copper wire have the same conductivity at 0° C.

The values obtained by comparison with a hard-drawn silver wire are then largely the source of the tables of specific resistances; but at the end of his appendix to the Report of the Electrical Standards Committee for 1864, Matthiessen gives values for hard-drawn silver and copper wires in terms of the new B.A. unit, expressed as the resistance of a wire one metre long, weighing one gramme.

These values are:—

Copper	·1469
Silver	·1682

The same table of values is given in the 'Philosophical Magazine' for 1865, where also is given a table of specific resistances for wires one metre long and one millimetre diameter, expressed in terms of the B.A. unit, and calculated from the value of the known conducting power of gold-silver alloy in terms of hard-drawn silver, and also in terms of the B.A. unit.

The values thus obtained do not agree at all well with the results calculated for the resistances of the gramme metre by the specific gravities of the elements furnished by tables.

Thus:—

	Calculated	Observed
Silver . .	·02048 . .	·02103
Copper . .	·02090 . .	·02104

Matthiessen states that he omitted to determine the specific gravity of the copper used in his experiments; he probably would not have obtained any very accurate results, as the weight of copper he used varied from 1·5 to 4 grammes.

The accuracy of Matthiessen's results seems to depend, therefore, on the accuracy of his determination of the resistance in terms of the B.A. unit of a hard-drawn silver wire; in considering, therefore, the question of the preparation of samples of copper of higher conductivities than Matthiessen obtained, it may be suggested that the cause of the difference is not explained by the fact that Matthiessen did not prepare pure copper, but by an error in the value of the standard with which the comparison was made.

I have, therefore, made a series of experiments on the resistance of pure silver wires; and, as a general result, have obtained a value identical with that of Matthiessen; the difference is not due, therefore, to an error in the standard employed, as far as my experiments go.

Matthiessen does not give anywhere the details of his measurements of the specific resistances of the metals in terms of the B.A. unit; in the B.A. Report he simply mentions that an approximate table is subjoined, not even stating the fact that the values are for a temperature of 0° C. I conclude, therefore, that these values are calculated out from the former, of which an account is given in the same B.A. Report, and which were performed at a temperature of 20° C.

I have, therefore, on this account, as well as for other reasons stated later, made my measurements at the temperature of the air, and believe that as his values were reduced by a temperature coefficient to values at 0° C., I shall, by using the same temperature coefficient, obtain results directly comparable with my own measurements.

For the measurement of the resistance of the specimens of wire a Wheatstone's bridge arrangement was employed. Two of the arms of the bridge were formed by a 10 and 1 standard B.A. unit, namely, 66 and G; these were so nearly 10 to 1, that they were taken to be in that ratio.

The third arm was $\frac{1}{3}$ of a B.A. unit, and in the fourth arm was the wire to be measured; this was stretched on a flat board, and soldered at the ends to copper plates, to which connecting wires were also soldered; the length of wire used was generally a little less than two metres, and the wires were, approximately, No. 18 B.W.G. The board had scales screwed to it at the two ends. The board and wire were placed in a long bath made of zinc, and filled with paraffin. Wires which were left in the bath for some days, and, in more than one case, several weeks, were not found to have been acted on by the oil.

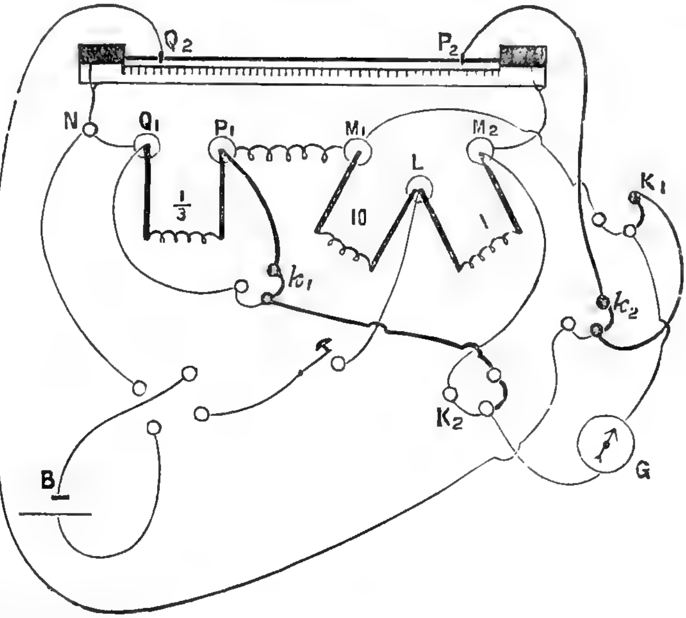
One end of the wire, P_2, Q_2, was connected by a binding screw, through an adjustable resistance, r ($\frac{1}{2}$ metre of copper wire), to the mercury cup, Q_1, in which was one of the legs of the $\frac{1}{3}$ coil, and also to a reversing key in the battery circuit. The $\frac{1}{3}$ and the 10 ohm coils were connected up together through an adjustable resistance, P_1 M_1; one leg of each of the coils 10 and 1 was in the same mercury cup, L; and the other end of the 1 B.A. unit was connected with the other end of the wire, P_2 Q_2.

A single Leclanché cell was connected with the reversing key, and the fourth point of this key was connected with the mercury cup L, into which the legs of 10 and 1 dipped. In this circuit there was also a touch key. The galvanometer circuit was always made, and thus there was no thermo-electric effect in the galvanometer circuit. To each of the mercury cups Q_1, P_1, M_1, M_2 were connected two thick wires with separate binding screws: one of these wires was welded to the copper plate at the bottom of the mercury cup. Each of these latter wires was connected with two way-keys; those in P_1 and Q_1 to the key k_1; those in M_1 to the key K_1; those in M_2 to the key K_2.

The base points of the keys K_1 and K_2 were connected with a delicate reflecting galvanometer, that employed for the comparison of the standards on the Fleming bridge. The base of the key k_1 was connected with the third point on the key K_2, and the third point, on the key K_1, was connected to the base point of a fourth key, k_2, the two other points on this key being connected with riders, with which contact could be made with two points on the wire P_2 Q_2; the riders had straight edges, and thus their position on the scales could be easily determined. In performing an experiment, the keys K_1 and K_2 were so connected that the mercury cups, and so the ends of the coils 10 and 1, were in circuit with the galvanometer. The resistance, P_1 M_1, was then varied till, on making the battery circuit, no deflection resulted. The ends of the 10 and 1 were then at the same potential, and as the other ends of these coils were connected with the same pole of the battery, there was the same fall of potential on the two lines.

The keys K_1 and K_2 were then reversed, and by the keys k_1 and k_2 one end of the $\frac{1}{3}$ coil and one point on the wire P_2 Q_2 were connected through the galvanometer, and afterwards the two other ends. The riders were adjusted till there was no deflection of the galvanometer. The length of wire between the two riders had then a resistance of $\frac{1}{10}$ that of the $\frac{1}{3}$ B.A. unit coil.

FIG. 10.



By means of the series of keys it was easy to repeat the observations, and to connect either end of the $\frac{1}{3}$ coil with the wire. The resistance P_1 M_1 did not often change during the experiments, as the room was at a constant temperature; any change in it only caused a shifting of the position of the riders. In each experiment, after all the adjustments, the bath was well stirred, and everything left for half an hour. It was generally found that the riders did not require any readjustment. The battery was reversed, and all the coils moved. The latter never caused any effect; sometimes the reversal of the battery caused a shifting of the two riders a millimetre or two in the same direction. Another reading was taken three or four hours after.

The coils, $\frac{1}{3}$, 10, and 1, were in water baths, and their temperature remained the same for hours together. The temperature of the paraffin bath was not so constant; it was kept well stirred, and a thermometer divided to 0°·2 C. never showed any difference in the temperature at the different ends of the bath when the readings were taken. The thermometer employed was Kew-corrected; and the corrections given were verified by recent comparison with a platinum thermometer by Mr. Griffiths.

Since the two standard coils employed were accurately in the ratio of 10 to 1, the accuracy of the resistance measurement depended entirely on the value of the $\frac{1}{3}$ B.A. unit. This was first made as nearly as possible $\frac{1}{3}$, but it was found that for the size of the wires measured (18 B.W.G.) this was too high a resistance; it had therefore to be reduced. For the determination of its value there was cut out in a block of paraffin wax a large central mercury cup, and outside this a circular channel; thick copper plates were cut to fit them, and both plates were well amalgamated. By means of this cup arrangement the three B.A. units (H., G., and Flat) were connected in multiple arc, and by means of stout copper rods the multiple-arc arrangement was connected with the mercury cups on the Fleming's bridge, and so compared with the $\frac{1}{3}$ B.A. unit. The following observations were taken:—

July 12, 1889: $\frac{1}{3}(18^\circ{\cdot}4)+986{\cdot}6$(b.w.d.)=M.A.$+24{\cdot}6$(b.w.d.)
July 22, 1889: $\frac{1}{3}(17^\circ{\cdot}4)+986$ (b.w.d.)=M.A.$+24{\cdot}1$(b.w.d.)
August 26, 1890: $\frac{1}{3}(16^\circ{\cdot}8)+986{\cdot}1$(b.w.d.)=M.A.$+23{\cdot}9$(b.w.d.)

The value of a bridge wire division (b.w.d.) is ·0000498 B.A. unit at 15°, and the wire has a temperature coefficient of ·00143.

It is evident from these series of values that the $\frac{1}{3}$ has not changed in resistance during the period of the experiments.

This comparison, however, introduced a possible error, as the temperature of the bridge wire at the time of experiment was not accurately known, and this is important when nearly the whole of the bridge wire is employed. To eliminate this possible error the $\frac{1}{3}$ was compared with four B.A. units in multiple arc. In this case a large number of bridge wire divisions had to be subtracted from the value of the $\frac{1}{3}$, and the whole number of bridge wire divisions entering into the calculation for the values of the $\frac{1}{3}$ was largely reduced. The four coils in multiple arc were (F, G, H, and Flat):—

Aug. 25, 1890: $\frac{1}{3}$, $16^\circ{\cdot}8+157$ (b.w.d.)=M.A.$+852{\cdot}05$ (b.w.d.).
Aug. 26, 1890: $\frac{1}{3}$, $16^\circ{\cdot}8+157{\cdot}5$ (b.w.d.)=M.A. $+851{\cdot}9$ (b.w.d.).

All the four coils were at the same temperature (16°·8). Their values are taken from the 'B.A. Report,' 1888:—

Flat	1·000448
F	1·000028
G	·99955
H	·99969

They give for the two multiple-arc arrangements the values ·33330 and ·24998. The connecting-rods have a resistance of ·00042, and the value of the $\frac{1}{3}$ at 16°·8 is ·28537 B.A. unit. Its temperature coefficient is ·0001 per 1° C.

To measure the lengths of the wires two microscopes with scales and verniers reading to ·1 of a millimetre were set up and firmly clamped in position; the distance between them was determined by means of a beam compass and the aid of a third microscope: the distance between this and the other two being directly read off on the beam compass for set positions of the verniers. The wires were cut with a fine fret-saw at the points corresponding to the position of the riders in the resistance measurements. Before weighing the wires were carefully cleaned with methylated spirit. The balance employed was the one used by Mr. Glazebrook for our determination of the specific resistance of mercury; the weights were balanced against one another, and in all cases double weighings were taken.

The specific gravity of most of the wires was determined; for this purpose distilled water was boiled and cooled rapidly, the coil of wire immersed, and the beaker and its contents placed under the receiver of an air-pump, which was connected with a water-pump; this was left running for two or three hours till all air-bubbles had disappeared; the weight of the wire in water was determined, and a second reading taken some hours later. As the weight of wire used was from 16 to 20 grammes, fairly accurate values for the specific gravity of the several wires were obtained, and thus the value for each wire in terms of the B.A. unit for the resistance to conduction between the opposite faces of a cube of the material was found.

Resistance of Various Specimens of Wire.

Wire	Date	Resistance of a wire such that 1 metre weighs 1 gramme at 18° C. in B.A. units		Specific gravity	Specific resistance per cc. at 18° C. in B.A. units × 10^{-9}	
		Hard-drawn	Annealed		Hard-drawn	Annealed
I.	July 22, 1889	—	1549	8·86	—	1743
	Nov. 6, 1889	—	1550	8·87	—	1745
II.	July 22, 1889	—	1545	8·88	—	1741
	Dec. 2, 1889	—	1546	8·89	—	1742
III.	Dec. 3, 1889	—	1713	8·87	—	1922
IV.	July 10, 1889	1578	—	8·89	1776	—
	Aug. 1, 1889	1578	—	8·89	1776	—
IV.′	Nov. 1, 1889	—	1511	8·885	—	1724
V.	July 31, 1889	1573	—	8·89	1770	—
	Oct. 30, 1889	1572	—	8·89	1770	—
V.′	July 20, 1889	—	1526	8·89	—	1712
	Aug. 2, 1889	—	1526	8·89	—	1713
	Aug. 8, 1889	—	1527	8·89	—	1716
VI.	Aug. 10, 1889	1546	—	8·94	1730	—
	Oct. 18, 1889	1549	—	8·94	1732	—
	July 10, 1890	1549	—	8·94	1731	—
	July 14, 1890	1548	—	not obsrvd.	—	—
VI.′	Aug. 8, 1889	—	1508	8·94	—	1688
	Oct. 11, 1889	—	1509	8·94	—	1688
VII.	Nov. 4, 1889	1543	—	8·946	1724	—
	July 15, 1890	1543	—	—	—	—
VIII.	Oct. 23, 1889	1700	—	8·95	1903	—
	Oct. 28, 1889	1702	—	—	—	—
IX.	Aug. 5, 1890	1572	—	8·90	1766	—
	Aug. 18, 1890	1572	—	8·90	1766	—
X.	Aug. 5, 1890	1573	—	8·91	1767	—
	Aug. 26, 1890	1569	—	8·92	1751	—
XI.	Aug. 27, 1890	1569	—	8·93	1750	—
Matthiessen's value reduced to 18°, using his own coefficient		1571	—	not given	1766·6	As calculated by Fleeming Jenkin and Fitzpatrick

The first object of these experiments was to test directly in comparison with the B.A. standards samples of copper wire of high conductivities, with the view of comparing them with Matthiessen's standard. Application was therefore made to several firms for high-conductivity copper wires. My thanks are due to those who sent samples.

A table of results for all the specimens tested is given, and it shows the variation in resistance of high-conductivity wires.

IV. and IV.′ are the same copper, but IV. is hard drawn, IV.′ is annealed; they were measured just as they were sent from the manufacturers; the same is true of V. and V.′, VI. and VI.′

It will be noticed that VI. and VI.′, which are of considerably less resistance than the other wires, are of higher specific gravity: the firm that sent them thus wrote of them: 'It is only occasionally we come across copper as high as this or high enough to be called the highest (in conductivity) we can produce. This copper has been produced electrolytically by our ordinary process.' How this copper was treated after electro-deposition I do not know. I am inclined to think from my own experience that this difference in density is due rather to the condition of the copper than to its relative purity. Matthiessen found that very small quantities of impurities reduced the conductivity 20 or 30 per cent., and a sufficient amount of impurities to cause this decrease in density from 8·94 to 8·90 must make a larger increase in the resistance of the copper.

The temperature coefficient is stated to be different for various specimens of metal, according to their purity. Matthiessen himself seems to have been of this opinion; but the mere difference in density of the metal might be expected to affect the alteration of conductivity with the same change in temperature. I have not been able to find any experiments bearing on this question. It is quite easy to obtain samples of wire of different density by varying the process of drawing, and the temperature coefficients of such wires might be found to be different.

Comparing V. and V.′ with VI. and VI.′ it is seen that with this increase of density there is a distinct diminution in the effect of annealing.

$$\left.\begin{array}{r} \text{IV.} - \text{IV.}' = \cdot 00677 \\ \text{V.} - \text{V.}' = \cdot 00577 \\ \text{VI.} - \text{VI.}' = \cdot 004 \end{array}\right\}$$

I thought it might be possible that VI.′ was not completely annealed, so, for a direct comparison, two specimens of VI., which had been measured hard drawn on July 10 and 14, 1890, were annealed; for this purpose a flat copper vessel was made of about 2 cm. height and 18 in diameter, with a closely fitting lid; the wire was packed in this between sheet asbestos, which had been previously heated; the vessel was filled up with lampblack, and heated over a big bunsen burner and gradually cooled; the process generally took about twenty-four hours; the wire was found not to be oxidised after the process was over.

Wire	Hard-drawn	Annealed	Difference
I.	1549	1510	·0039
II.	1548	1509	·0039

The difference Matthiessen obtained was ·0038.

The above method of annealing was found very effective. Silver wires, which on annealing decrease 10 per cent. in resistance, gave the same value after a second annealing as they did on the first occasion.

Wire VII. was a wire sent me by Mr. H. A. Taylor, and had to be drawn down before it could be measured; another piece of the same wire drawn down on a different occasion gave the same value; this wire has the lowest resistance of any I have obtained; it has, too, the highest specific gravity. Mr. Taylor says of it 'that it has a higher temperature coefficient than that given by Matthiessen.'

VIII. was a sample of wire obtained from Germany, and said to be electrolytically prepared; its high resistance is, I think, due to the presence of oxide, as I fused some of it in hydrogen, and when measured partially annealed it gave the value ·1566 at 18° for the wire, 1 metre weighing 1 gramme.

IX., X., and XI. are wires of my own preparation. Pure copper was prepared electrolytically by Messrs. Sutton, of Norwich, and supplied me in thin sheet, and this was fused in a porcelain tube 18 centimetres in length and 1 centimetre in diameter; the tube was fitted up in a small furnace made of sheet iron, and lined with ganister; this was heated rapidly in a blast flame led in at the bottom. Some difficulty was experienced in obtaining the copper in a solid cylinder. In the early experiments hydrogen was passed into the tube while the copper was being fused, and was made to bubble through the molten copper; on breaking the tube the copper was found to be full of small holes; the copper had absorbed the hydrogen at the high temperature and given it off again on cooling; on another occasion the copper was fused down in hydrogen, and the tube was connected with a water-pump and exhausted and the copper allowed to cool in a vacuum; this gave a more continuous cylinder. It was found best to fuse the copper under borax, after previous reduction; a good cylinder of the metal was thus obtained.

I was unfortunately not able to draw down the copper for myself; this was very kindly done for me by Messrs. Smith, of Halifax, and Messrs. Johnson & Matthey. The porcelain tubes had been prepared of such a size that the cylinder of copper could be drawn without further heating; the copper, therefore, was not fused after it left my hands.

Two sheets of the electrolytically prepared copper were fused on different days, and one cylinder was sent to Messrs. Smith to be drawn, and the other to Messrs. Johnson & Matthey.

Wires IX. were drawn by Messrs. Smith, wires X. by Messrs. Johnson & Matthey.

Wire XI. was drawn by Messrs. Johnson & Matthey from a sample of copper which I prepared by electrolysis from a pure solution of copper sulphate; the copper was deposited on a plate of copper, which had had its surface rubbed over with graphite; by this means the deposited copper was easily stripped off the plate; the other plate was of platinum. After a time the solution was changed; the deposition was very slow, as it was thought that there would be less likelihood of copper sulphate getting in between the layers of copper. The deposit was boiled with dilute sulphuric acid and then in water, and was afterwards fused as above described.

Wires IX. were measured as received; this accounts for the close agreement between the two determinations. Wires X. and XI. I had to draw down further to measure them on my bridge.

Wires X. (2) and XI. were drawn down with great care and not so much as X. (1).

Below is a table of the measurements made for the determination of their specific resistances:—

Wire	Value of 1/3	Temp.	Weight of wire	Length of wire for determination of resistance.	Length cut and weighed	Resistance of gramme per metre	
IX. (1)	·28547	17°·9	20·388	192·1	192·5	1574	18°·3
„ (2)	·28541	17°·4	20·153	192·4	190·45	1569	17°·5
X. (1)	·28550	18°·2	19·708	189·3	188·8	1577	18°·6
„ (2)	·28536	16°·8	20·252	192·39	192·34	1561	17°·1
XI.	·28535	16°·7	20·262	192·11	192·51	1563	17°·2

These values reduced to a common temperature of 18° are:—

IX. (1) . .	·1572	
IX. (2) . .	·1572	Mean value
X. (1) . .	·1573	·1571
X. (2) . .	·1569	B.A. unit.
XI. . .	·1569	

Thus ·1571 B.A. unit is the resistance at 18° of a metre of hard-drawn copper wire weighing 1 gramme.

Matthiessen in the B.A. Report [1] gives as the resistance of a gramme metre at 0° ·1469 B.A. unit.

I have calculated from this the value at 18°, using the temperature coefficient that he gives in his paper on the influence of temperature on the conducting power of metals. I have taken no account of the terms in t^2 as they practically cancel one another.

$$R.\ 18^\circ = R^\circ(1 + \cdot 0038701t).$$
$$R.\ 18^\circ = \cdot 1571.$$

This is the value that I have obtained as the mean of my own observations.

All my observations were taken at the temperature of the room, and in the table above the values for the different wires are given at the observed temperature, and then all reduced to a common temperature of 18° C. Most observations of this character are taken at the temperature of 0° C., but on the whole it seemed more satisfactory to work at the temperature of the room. In the comparison of the B.A. units I have found that with a difference of temperature between coils which are connected by thick pieces of copper there is always conduction of heat, and it is impossible to tell accurately what is the real temperature of the coils.

My observations were made in the B.A. room at the Cavendish Laboratory, which has a north aspect, and often the temperature did not alter more than a few tenths of a degree, whilst the temperature of the coil baths often remained perfectly steady for several consecutive days. I cannot find any observations of Matthiessen's at 0° C.; certainly his observations on copper were made at 18°, and, consequently, if the value given by him at 0° C. has been obtained by the use of a temperature coefficient, my value might be expected to agree with his at 18°, the tem-

[1] *B.A. Report*, 1864, or *Phil. Mag.* 1865.

perature of his observation, supposing the samples of copper of the same character.

Matthiessen's results are given in terms of a gramme per metre, and for wires of metre length and 1 mm. in diameter.

In a paper in the 'Philosophical Magazine,' Matthiessen gives the value for hard-drawn copper in these terms as—

·02104 B.A.

From his value for the gramme metre, using the specific gravity 8·95 given by tables, the same quantity was calculated, but gave the result ·0209; in a note added he states that had he used the specific gravity 8·91 his results would have been more nearly alike; but a specific gravity 8·90, I find, would give an identical value.

This would show, then, that Matthiessen's own table, calculated for values obtained by comparison with hard-drawn silver, is accurate. I have tested silver wires, but have not had time to draw up the results in tabular form; and I obtained an almost identical value for hard-drawn silver wire, as supplied me from Messrs. Johnson & Matthey, as is given by Matthiessen for the resistance of a gramme per metre.

It will be observed that wires IX. have the specific gravity 8·90, and give a value in terms of B.A. units for a cubic centimetre of the material identical with Matthiessen's value; this value is not given directly by Matthiessen, but is calculated from his results by Fleeming Jenkin, and given in his table in his book 'Electricity and Magnetism': it is 1·652 microhms. I have calculated it from Matthiessen's value, given in the 'Philosophical Magazine,' and get the number 1·653. Using the same temperature coefficient as before, the resistance at 18° C. of a cubic centimetre of hard-drawn copper is $1766{\cdot}6 \times 10^{-9}$ B.A. units.

On comparing the values for wires IX., X., and XI. in these terms, the results do not agree so well together as when expressed in terms of the gramme metre; there is a corresponding difference in the values of the specific gravities; these latter have been very carefully determined, and the experiments repeated with the results given.

Wires, therefore, of the same resistance expressed for grammes per metre, may give a very different result, when expressed as per cubic centimetre: attention has been drawn to this fact in the discussion on the Elmore copper in the 'Electrician.'[1] M. Roux, of Paris, in a letter gives the following table for high-conductivity wire from a paper of M. Hospitalier in 'L'Electricien,' 1887; this paper I have unfortunately not been able to see.

Density	8·897	9·32	9·6
Conductivity, equal volume	102·4	106·7	110·8
Conductivity, equal weight	101·7	101·2	101·6

What is 100 in the conductivity units is not expressed. M. Roux thinks that the former, *i.e.*, for equal volume, is the more rational method of expressing the result.

Matthiessen expressed all his results in terms of equal weight, justifying it by the greater accuracy obtainable when working with small weights of wires. Small errors in the value of the specific gravity are easily made, and cause a similar error in the result for equal volumes of

[1] *Electrician*, December 7, 1888.

different wires; unless working with long lengths of thick wire the weight of the wire is small. The weight of the water displaced cannot be determined within ·5 to 1 milligramme, and that only with care: this error in ·5 of a gramme means only an accuracy of 1 in 500. The values given in my table are probably correct to 1 in 1,500 or 1 in 2,000, as the weight of water displaced was in all cases over 2 grammes. Results, therefore, for resistances of wires of equal weight are the most trustworthy, and, I think, also the most satisfactory if used to express the resistance of a material and not of any given wire.

Wires X. (1) and X. (2) are of the same copper, but drawn down separately: X. (1) was beginning to fray, and another specimen of the same copper drawn down still further had on this account to be rejected; this has affected the resistance value expressed in both ways. Thus:—

X. (1) . . .	·1573 . .	1767
X. (2) . . .	·1569 . .	1751

but much more so when expressed for equal volumes. In both the copper is of the same quality.

It will be noticed that with increase of specific gravity there is a decrease of resistance, even when the results are expressed for wires of equal weight. The resistance diminishes, therefore, more rapidly than the density increases. Wires of the same quality may, in consequence of a difference in drawing, have a different density, and so the results expressed in terms of equal volume will differ considerably, while those for equal weight are the same, or approximately so.

The values obtained for IX., X., and XI. are so nearly identical that it is not unfair to conclude that they are samples of pure copper; their value is identical with that obtained by Matthiessen at, I believe, the same temperature. The greater difference obtained at 0° C. between Matthiessen's value and samples of copper tested now at that temperature is probably due to the fact that Matthiessen's value was not determined at 0°, but reduced in value for that temperature from observations, as stated above, at about 20° C.

The higher conductivity or less resistance for the two samples given in the table is due, not to increased purity in the preparation of the copper, but to the difference in the process of preparation, whereby a sample of greater density is obtained than results from the working up of small quantities of copper in the laboratory.

A sample of copper has been prepared by chemical means with the help of my friend Mr. Skinner, but has not yet been measured.

APPENDIX IV.

A Comparison of a Platinum Thermometer with some Mercury Thermometers at Low Temperatures. By E. H. GRIFFITHS, *M.A., Sidney College, Cambridge.*

The following communication describes the mode of constructing an air-tight platinum thermometer for use at low temperatures. The thermometer was graduated by means of the freezing and boiling points of water, and as regards intermediate points Regnault's determinations of the temperature and pressure of aqueous vapour were adopted. The precautions observed in the construction of the apparatus, and in the method of observation, are described. The thermometer was tested by comparison with a number of thermometers standardised at Kew. The curves, showing the result of these determinations, are in remarkably close agreement, and when the observations were sufficiently numerous it appeared possible to calibrate the bore as accurately as by the usual more laborious process. The further advantage of this method is that thermometers can be compared under the conditions in which they are to be used.

In a communication to the Royal Society read on June 19, 1890, I described a method of constructing and graduating platinum thermometers, and gave a table of boiling and freezing points for various substances lying between 100° and 500°, determined by means of these instruments.

Subsequent observations indicate that a slight change appears to be taking place in the readings of these thermometers. I attribute this (1) to alterations in the glass, (2) to presence of moisture in the tube—the asbestos roll on which the spiral was wound being highly hygroscopic. I therefore decided to construct a thermometer in which there should be no contact between the glass and the platinum, and which should be thoroughly dry and hermetically sealed.

I was unable to discover any suitable non-conductor capable of resisting high temperatures; but in anthracene (melting-point 213°) I found a substance suitable in every respect for use at low temperatures. I subjected a sample to severe tests, and, up to a temperature of about 130°, found it to be a better insulator than paraffin.

The leads to the coil were constructed of silver, the inner one a rod and the outer a tube. The resistance of these leads was about ·001 ohm, and therefore any change in the external resistance, caused by change of temperature, might be disregarded. The silver leads approached to within about 1 inch of the spiral, and were connected to it by moderately thick platinum wires; thus a flow of heat from the spiral to the silver was diminished. The wire forming the coil was about 56 inches in length, and had a diameter of ·005 inch. The spiral was about 2 inches long, having a resistance of about 13·5 ohms at 0° C., and the external diameter of the covering tube was about ·3 inch. The ends of the asbestos roll were made of greater diameter than the portion on which the spiral was wound, and thus there was no glass contact. The tube and contents were heated up to a temperature of several hundred degrees, and dried air passed through for some hours. It was then exhausted and the open end placed under the surface of melted anthracene, which was allowed to rise until nearly in contact with the coil. When cool, the whole of the thermometer from the spiral to the upper end (about 13 inches) was a solid mass, while the spiral and asbestos roll were perfectly dry and in an almost vacuous space. I have taken nearly 600 observations with this thermometer and cannot detect any signs of change. When the lower part was undergoing rapid changes in temperature, thermo-electric effects showed themselves, but by reversing the battery and galvanometer connections during each reading these effects were eliminated. A low-resistance galvanometer was used, and the current which passed through the thermometer when determining its resistance did not exceed one hundredth of an ampère. To illustrate the closeness of the agreement in the results obtained at different times I give the following determinations of the resistance at a temperature of 100° determined in the usual manner by means of a hypsometer with manometer attached. Full corrections were made in the barometric reading, and the results reduced to lat. 45°.

Date	Temperature	Resistance (after corr. for temp. of coils)
July 26	100°C.	18·2029
„ 27	100°C.	18·2034
August 12	100°C.	18·2025
„ 13	100°C.	18·2031
Mean		18·2030

The expression for the platinum temperature by this thermometer was

$$\frac{R - 13{\cdot}5219}{4{\cdot}6811} \times 100, \text{ again } \frac{R_{100}}{R_{\circ}} = 1{\cdot}3462,$$

almost exactly agreeing with the coefficient of the wire in Mr. Callendar's air thermometer ('Phil. Trans.' A. 1887).

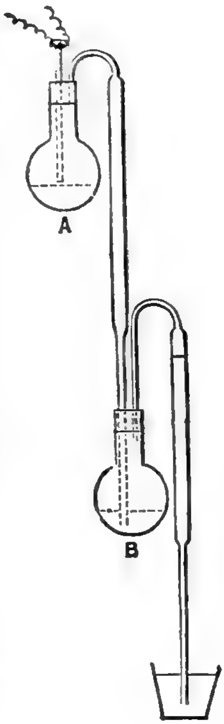
Mr. G. M. Clark, B.A. (Sidney Coll., Cambridge), now joined me in the investigation, and as we proposed to use this thermometer for the calibration and graduation of mercury thermometers between 0° and 100°, we decided to obtain intermediate temperatures by means of Regnault's numbers connecting the temperature and pressure of aqueous vapour. For this purpose we constructed a large iron tank with two plate-glass sides, holding about 16 gallons of water, and through two holes bored in the bottom inserted two barometer tubes, the upper 16 inches of each being within the tank. One of these was used as a standard barometer, and was prepared with great care, the distilled mercury with which it was filled having been boiled in the tube for more than six hours. The internal diameter of the tube was 14 mm., and the absence of any meniscus was very marked. If the level of the surface of the water in the tank was below the top of the barometer, and the water warmed, the sublimation of mercury in the vacuous space was observable. The second barometer was made from the same length of tubing as the first, and communicated at its upper extremity with a small flask (A), in which was placed the platinum thermometer.

Distilled water was boiled in vacuo for some hours, to expel all traces of air. The flask and barometer tube were then exhausted by means of an air-pump, and the lower end of the tube placed in a flask (B) containing the previously boiled water, which rushed up, filling the tube and flask (A).

The water remaining in B was then boiled until this flask and a bent tube passing from it into a basin of mercury, 30 inches beneath, were completely filled with steam, and, on cooling, the height of mercury in the tube enabled us to determine that the pressure on its surface was that of aqueous vapour only. The water in the upper flask was then boiled for many hours, and only allowed to cool occasionally to permit of the water in the lower flask being boiled away. To prevent access of air the steam was driven off through the mercury. When the water in flask A was reduced to about a tablespoonful, the boiling was stopped, and the level of the mercury was raised until it flowed back first into flask B and thence into the barometer tube, as flask A cooled.

The open end of the barometer tube was then sealed, the flask B replaced by a small cup of dry mercury, and the end of the tube opened below the surface. The water remaining on the top of the column was driven back into the flask by pouring hot water over the tube.

FIG. 11.



During our experiments, water occasionally collected on the mercury, but by means of a concave mirror it was driven back into the flask; the mirror was of course removed some time before an observation was taken.

The tank, filled with water, was maintained at any required temperature by means of a gas regulator. The lower parts of the barometer tubes were screened by sheets of asbestos, and the two cups were connected by a small siphon. The glass sides of the tank were covered with white paper to prevent radiation; openings were left for observations, during which the water in the tank was kept in a continual state of agitation by the oscillation of a large paddle driven by a water motor. The paddle, fixed in one corner of the lid, swept across the tank, driving the water before it, and lifting it at the same time. We have tried several forms of stirrers, and we believe this to be a more effective form than a screw or a plunger.

The difference in the height of the mercury in the two barometer tubes was ascertained by the kathetometer G. 33, in the Cavendish Laboratory, and by means of it readings could be taken to ·50 mm. Care was taken to bring both levels horizontal before each observation.

As the coefficient of expansion of the kathetometer scale was unknown and the temperature of the room usually about 20°C., we decided to compare it with the standard scale R, whose coefficient of expansion and scale errors had been determined by the Standards Department of the Board of Trade.[1]

Twenty-one comparisons were made (greatest divergence from the mean ·10 mm.), and the result was as follows:—300·35 mm. on kathetometer scale at 20°=300·35489 of Board of Trade Standard (S.S.) at 0°.

Thus no scale correction was necessary.

The difference (D) of the mercury columns was corrected for temperature, pressure of mercury vapour and latitude, and the resulting length denoted by D_0: the temperature corresponding to D_0 was deduced from the very full table given in Part 3 of Carnelley's 'Melting and Boiling Point Tables.'

The extremities of the curve (at 0° and 100°) having been determined, it was only necessary to get points between 30° and 80°.

Ninety observations were taken, and although occasional divergences presented themselves, the mean path gives a curve which we believe to be

[1] Standard metre, verified June 1882, designated R in Mr. Chaney's report.

within less than ·02° of the true path at all points. It agrees closely with the curve obtained by Mr. Callendar from the parabola

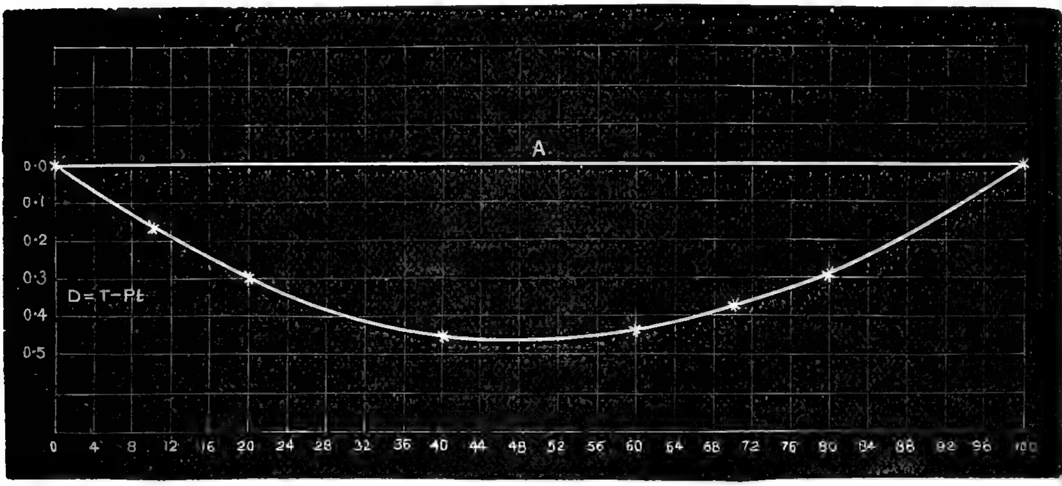
$$1{\cdot}57\left[\left(\frac{t}{100}\right)^2-\frac{t}{100}\right],$$

by measuring one-tenth of the ordinate along the abscissa.[1]

The following equation, however, represents its path more accurately.

$y = {\cdot}018795t - {\cdot}0001991t^2 + {\cdot}0000001115t^3$. The curve itself is shown in Chart A, fig. 12.

FIG. 12.



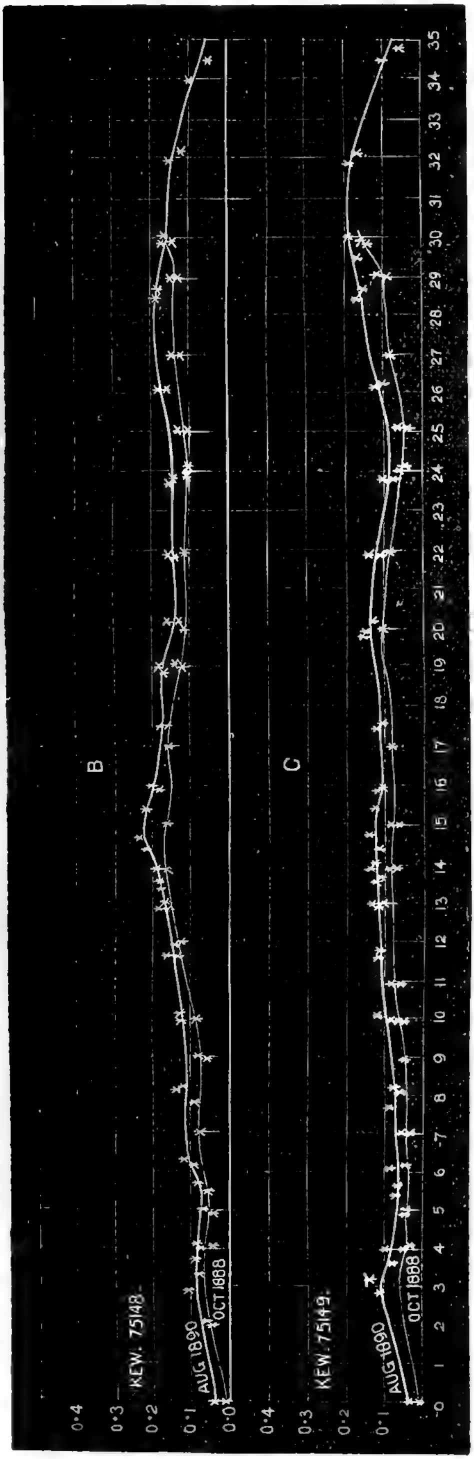
We proceeded to test our conclusions by comparison with thermometers standardised at Kew; for this purpose a rotating annular ring, through the centre of which the platinum thermometer passed, was inserted in the lid of the tank, in such a manner that the mercury thermometers, fixed in holes bored near its circumference, could successively be brought into the field of view of the kathetometer without any re-adjustment of the telescope; the thermometers were then read by one observer, whilst the platinum resistances were taken by the other. The freezing-points were not, however, determined by this method, but by direct immersion in powdered ice, adopting the precautions recommended by Guillaume in his 'Thermométrie de Précision.'

The following curves were then drawn, which indicate the result of the comparison of our platinum thermometer with those standardised at Kew.

Curve	Thermometer, Kew No.	Standardised
B	75148	October 1888.
C	75149	October 1888.
D	43762	May 1885.
E	8394	December 1880, January 1882, April 1888.

[1] It must be remembered that Callendar's difference curve gives the connection between platinum and air thermometer temperatures, whilst Regnault used a mercury thermometer (M.A.S. XXI.), and thus curve A gives the relation between platinum and mercury thermometer temperature.

All these thermometers were made by Hicks; the first three were kindly placed at our disposal by Mr. R. T. Glazebrook; the last is one of those referred to by Mr. W. N. Shaw in a communication to the B.A.



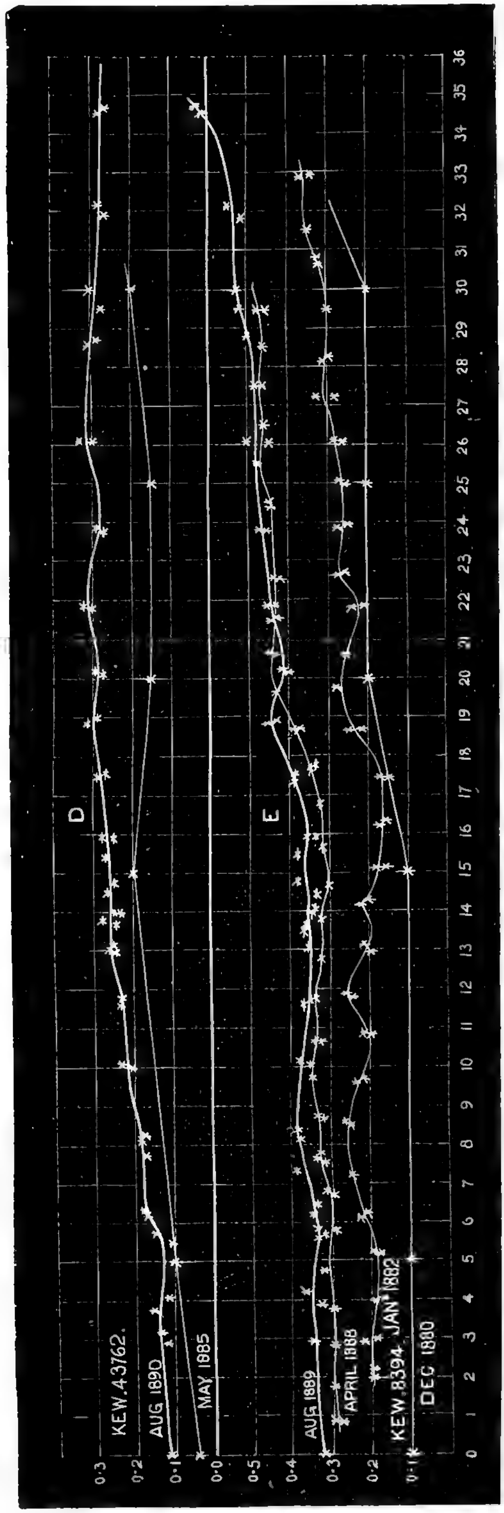


FIG. 14.

during the Bath Meeting, the successive curves of which, then exhibited by him, he has kindly allowed us to copy.

In these diagrams the abscissæ represent the temperature—in the strong curves, that obtained by us, and in the faint, that obtained at Kew: the ordinates in each case being the divergence of the actual readings from these results. Where crosses occur at almost identical temperatures they indicate observations separated by a considerable interval of time; in no case did less than 20 minutes elapse, whilst in some several days.

Three only of our observations are unrecorded on these charts, and in each case, owing to imperfect light, interruptions, &c., these experiments were regarded as doubtful before their results were deduced.

The gradual rise of the zero point is clearly indicated; apparent discrepancies are probably due to the fact that the Kew determinations are less frequent than ours, and as a consequence many of the smaller deviations have escaped notice.

The results show:—

1. That thermometers whose range does not include 0° and 100° may have certain fixed points determined by this method.

2. That an actual calibration of a mercury thermometer can also be readily accomplished.

3. That the platinum thermometer, properly constructed, may serve as a standard by which to trace the changes which may take place in mercury thermometers.

4. That since the readings of the platinum thermometer are independent of the extent of the stem-immersion, it can be conveniently employed for the graduation of thermometers partially immersed, as in ordinary use.

We have since calibrated about twenty thermometers by this method, and we believe the results to be satisfactory in all cases.

APPENDIX V.

On the Absolute Resistance of Mercury. *By* R. T. GLAZEBROOK, *F.R.S.*

The following table gives the results of experiments made since 1882 on the absolute resistance of mercury. The first eight lines relate to experiments in which the resistance of a wire has been found absolutely and then expressed in terms of the resistance of mercury by direct observation. In the next four lines the results of comparisons between certain coils of wire and the resistance of mercury are given. It will be noticed that the value found by Lord Rayleigh for the resistance of 100 cm. of mercury in B.A. units is considerably in excess of the results of other experimenters. If in obtaining from his value of the B.A. unit expressed in ohms the value of the ohm in mercury we use ·9535 instead of ·9541, Lord Rayleigh's values 106·24 and 106·21 become 106·30 and 106·27, and the mean result 106·28 is hereby raised to 106·30.

The observers whose results are given in the last seven lines, with the exception of Lorenz, did not themselves directly compare the results of their absolute determinations with the resistance of mercury, but with coils usually of german silver, the value of which in mercury units was certified either by Siemens or Strecker.

Value of Ohm Expressed as the Resistance of a Column of Mercury.

–	Observer	Date	Method	Value of B.A.U. in Ohms	Value of 100 Centimetres of Mercury in B.A.U.	Value of Ohm in Centimetres of Mercury
1	Lord Rayleigh	1882	Rotating coil	·98651	·95412	106·24
2	Lord Rayleigh	1883	Lorenz method	·98677	—	106·21
3	G. Wiedemann	1884	Rotation through 180°	—	—	106·19
4	Mascart	1884	Induced current	·98611	·95374	106·33
5	Rowland	1887	Mean of several methods	·98644	·95349	106·32
6	Kohlrausch	1887	Damping of magnets	·98660	·95338	106·32
7	Glazebrook	1882 and 1888	Induced currents	·98665	·95352	106·29
8	Wuilleumeier	1890	—	·98686	·95355	106·27
			Mean	·98656		
9	Strecker	1885	An absolute determination of resistance was not made. The value ·98656 has been used.	—	·95334	106·32
10	Hutchinson	1888		—	·95352	106·30
11	Salvioni	1890		—	·95332	106·33
12	„ —	—		—	·95354	106·30
			Mean	. . .	·95355	106·28
13	H. F. Weber	1884	Induced current	Absolute measurements compared with german silver wire coils issued by Siemens or Strecker.		105·37
14	H. F. Weber	—	Rotating coil			106·16
15	Roiti	1884	Mean effect of induced current			105·89
16	Himstedt	1885	—			105·98
17	Dorn	1889	Damping of a magnet			106·24
18	Wild	1883	Damping of a magnet			106·03
19	Lorenz	1885	Lorenz method			105·93

The value given by Salvioni in his paper ('Rendiconti della R. Accademia dei Lincei,' vol. v. fasc. 7) is ·95404. Owing to a mistake in calculation, in consequence of which a correction was applied with the wrong sign, the value sent to him from Cambridge for his B.A. standard was in error by ·0005. When this is corrected his value becomes ·95354, thus agreeing very closely with the others. Salvioni's value in line 11 is obtained through a coil of Strecker's.

Fifth Report of the Committee, consisting of Professors FITZGERALD (*Chairman*), ARMSTRONG *and* O. J. LODGE (*Secretaries*), Sir WILLIAM THOMSON, Lord RAYLEIGH, J. J. THOMSON, SCHUSTER, POYNTING, CRUM BROWN, RAMSAY, FRANKLAND, TILDEN, HARTLEY, S. P. THOMPSON, McLEOD, ROBERTS-AUSTEN, RÜCKER, REINOLD, CAREY FOSTER, H. B. DIXON, *and* JOHN M. THOMSON, Captain ABNEY, DRS. GLADSTONE, HOPKINSON, *and* FLEMING, *and* Messrs. CROOKES, SHELFORD BIDWELL, W. N. SHAW, J. LARMOR, J. T. BOTTOMLEY, R. T. GLAZEBROOK, J. BROWN, *and* E. J. LOVE, *appointed for the purpose of considering the subject of Electrolysis in its Physical and Chemical Bearings.*

DURING the past year the following communications bearing on the subject of electrolysis have been published by members of the Committee:—

Mr. W. N. Shaw: 'On the Relation between Viscosity and Conductivity of Electrolytes.' ('Proc. Camb. Phil. Soc.' November 1889.)

In this communication Mr. Shaw criticises the observations and conclusions of Wiedemann concerning the intimate connection between electric resistance and ordinary viscosity in liquids, and of the independence between ionic migration and electric endosmose. He quotes an observation of Kohlrausch, showing that when fused silver iodide solidifies there is no discontinuous change of conductivity at the melting-point. He further examines how far the precise ionic velocity, calculated by Kohlrausch and verified by Lodge, can be reconciled with the view of electro-decomposition by help of complex molecular aggregates, as opposed to the simple view of free or dissociated atoms; and concludes that the molecular-aggregate theory may turn out capable of explaining all the known facts.

Mr. A. P. Chattock has kindly translated for the Committee an abstract by Dr. J. Gubkin, from Professor Warburg's laboratory (Wiedemann's *Annalen*, 32, page 114), 'On the Electrolytic Separation of Metal at the free surface of a Salt in solution.' The translation is printed below.

Electrolytic Separation of Metal at the free Surface of a Salt in Solution.
By Dr. J. GUBKIN.

1. When a current of electricity passes from the solution of a salt into a vapour or a gas, electrolytic separation of the metal must occur at the surface of the liquid. At the suggestion of Herr Warburg I have made one or two experiments to determine how the separation of metal takes place in such a case.

2. It is best to render the space above the liquid free of air. For this purpose the apparatus shown in Fig. 1 was used. It consisted of a glass vessel in which two platinum wires, B and C, were sealed, B being plated electrolytically with the metal to be separated from the solution. The latter was introduced to the level D′ E′ and boiled for about ten minutes, until its surface had sunk 4 or 5 mm. below the point of the wire C. While the vapour was still escaping the vessel was closed at F with shellac; and, after cooling, the neck was melted off at A. The apparatus then appeared sufficiently free from air.

In order to reduce the vapour-pressure, the lower part of the vessel was placed in ice, the upper part being freed by warming from any liquid that still clung to it.

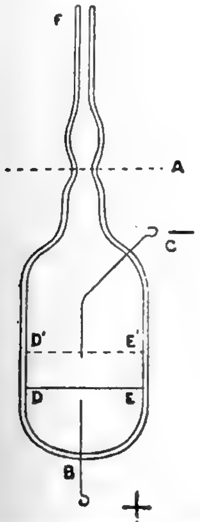
A battery of 1,000 Planté accumulators was then connected, the positive pole with B, the negative with C; upon which there appeared at C the well-known negative glow.

3. When the vessel contained nitrate of silver the following was observed: Soon after putting on the current a small round disc of bright silver was formed just underneath C. As the disc increased in diameter it darkened at the centre, and there was formed upon it a series of light and dark concentric rings, which were sometimes coloured—some of these showing radial markings, which gave them the appearance of divided circles. The disc did not sink, provided the apparatus was kept from shaking.

4. With a solution of zinc sulphate there was no separation of metal to be seen; but on looking at the surface D E from below, white flocculent masses of zinc oxide were visible slowly sinking through the liquid. The zinc on separation by the current was thus immediately oxidised.

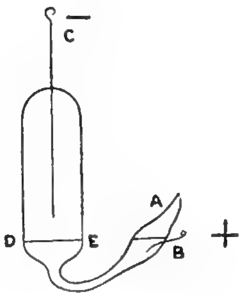
5. For experiments with a solution of platinum chloride the apparatus in Fig. 2 was used. In this the chlorine was collected over B.

FIG. 1.



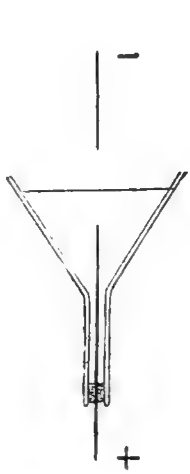
One-third natural size.

FIG. 2.



One-third natural size.

FIG. 3.



One-third natural size.

A short time after closing the circuit there was visible just opposite C a small lump of dead black platinum. On stopping the current this floated to the side of the vessel, but returned to its original position just opposite C when the current was again started, thus preventing the formation of a fresh lump. Very probably this phenomenon was due to electric forces.

6. These experiments may also be carried out in air by means of an induction coil. The liquid is contained in a funnel, as in Fig. 3, and the discharge at 'break' furnishes the necessary current, the spark gaps between the solution and the cathode being arranged to prevent a discharge at 'make' from taking place. In this manner experiments with silver, zinc, and copper solutions were carried out, with results substantially the same as those described above, except that here the space flowed through by the current, and consequently the diameter of the silver disc was

smaller than before. The concentric rings were, however, clearly visible. ('Phys. Inst. der Univ. Freiburg, i. B.')

In connection with this deposition of metal obtained on the upper surface of a liquid, Professor Ostwald's discovery of the deposition of copper at the boundary of a semi-permeable partition may also be called attention to. (See below.)

Mr. J. Brown has communicated a paper, which appeared in the 'Phil. Mag.' for July 1890, 'On the Electrification of the Effluvia from Chemical or from Voltaic Reactions,' wherein he discusses and extends the observations of Mr. Enright on the electrification detected above a vessel in which chemical ebullition is occurring. He considers that the electrification is not due to friction or any contact effects, but that it has a voltaic or electrolytic significance. If so, the observations of Mr. Enright ('Phil. Mag.' January 1890, page 56) have more importance than a criticism by Lodge ('Phil. Mag.' March 1890, page 292) was disposed to concede to them. It is to be hoped that Mr. Enright will pursue the subject, and obtain definite evidence as to how the spray-matter receives its charge.

Mr. Brown's summary of conclusions is as follows:—

When gas is evolved in a chemical or voltaic reaction, the effluvium (*i.e.* this gas or something carried up with it) is usually, as shown by Mr. Enright, electrically charged. So far as these present experiments show, no electrification is produced by simple effervescence unaccompanied by chemical changes.

The sign of the electrification is influenced by the kind of chemical or voltaic action taking place, and is apparently not due to any contact effect.

When the effluvium is that given off from zinc dissolving in HCl (taken as a typical experiment), and consists of hydrogen accompanied by foggy matter, it is not decided whether the charge is given originally to the gas or the fog particles, though the balance of evidence inclines perhaps towards the latter view. The fog in question is formed apparently at, or nearly at, the same place as the gas; and the nature of its charge (if any) is therefore possibly influenced by the voltaic condition there present.

The gas, or effluvium, from the decomposition of a liquid by a current from the poles of a separate battery immersed in it (voltameter) appears also to be electrified.

Concerning the verification of Ohm's law in electrolytes which has been carried out by members of the Committee, or rather concerning the wider question of the validity of the Maxwell-Chrystal method in general, the Committee have been favoured with a letter from Professor Chrystal, which is reproduced with a sufficient introduction here.

Verification of Ohm's Law.

In one of the circulars issued to the Electrolysis Committee of the British Association, viz. that dated June 24, 1886, Professor Fitzgerald suggested an objection to the complete validity of the theory of the experimental method of verifying Ohm's law with twelve-figure accuracy, devised by Clerk Maxwell and carried out by Mr. Chrystal; doing so in the following words:—

'There is an objection to this method that I have not seen noticed. Maxwell assumes that you can expand in powers of $\frac{C^2}{S^2}$. Now, if the law were the positive value of $\left(\frac{C}{S}\right)^n$, where n differs very slightly from unity, the method would fail, for the current would vanish both in the numerator and in the denominator of Maxwell's expansion.'

Maxwell's theory is given in the Glasgow volume of the British Association for 1876.

Recently Dr. Fison seems to have promulgated the same objection, and consequently Professor Fitzgerald wrote to Professor Chrystal about it. In reply he received a very interesting letter, which he has passed on to me, and from which I extract the portion referring to this subject.

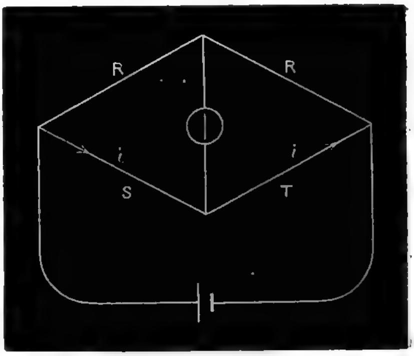
OLIVER J. LODGE.

Letter from Professor Chrystal to Professor Fitzgerald.

. . . The problem which I set myself in the Ohm's law experiment was to show that when a Wheatstone's bridge is balanced for any electromotive force in the battery circuit, it is balanced for every, or, to put it safely, for widely varying, electromotive force.

The theoretical part of the paper, for which Maxwell was responsible, I do not remember ever having examined from a sceptical or logical point of view.

FIG. 4.



It now appears to me that we ought to reason as follows:—

In order to find the necessary condition upon the resistance-function E/C, let us make matters as simple as possible by considering a bridge in which two arms, R, R, are of equal resistance, of the same metal, and *alike in every respect*. Let the two other resistances S and T be made of two different metals, say of Cu and Fe. Let the length and section of S be l and ω; and the length and section of T be l' and ω'. The specific resistance must in each case be a function of the current intensity (current per unit of section). Temperature is supposed kept constant, of course. Let the whole current flowing through S and T when there is a balance be i, the specific resistances of S and T will be $\phi\,(i/\omega)$ and $\psi\,(i/\omega')$ respectively.

The condition for balance will therefore be

$$(l/\omega)\,\phi\,(i/\omega)=(l'/\omega')\,\psi\,(i/\omega') \quad . \quad . \quad . \quad . \quad . \quad (1);$$

and this equation must, by the result of the experiment, *hold for all values of 'i.'*

Let us suppose that we alter the length of the iron wire S to l'', then there will be a corresponding section, ω'', for which there will again be a balance; so that we must have

$$(l''/\omega'')\,\phi\,(i/\omega'')=(l'/\omega')\,\psi\,(i/\omega') \quad . \quad . \quad . \quad (2);$$

and this again must hold for all values of i.

Combining (1) and (2), we get

$$(l/\omega)\,\phi\,(i/\omega)=(l''/\omega'')\,\phi\,(i/\omega'') \quad . \quad . \quad . \quad . \quad (3).$$

From this equation we can readily determine the form of the function ϕ.

If we put $\mu=\omega''/\omega$, $\lambda=l''\omega/l\omega''$, $x=i/\omega''$, we get

$$\phi\,(\mu\,x)=\lambda\,\phi\,(x);$$

whence, putting $x=\mu\,x$, we get

$$\phi\,(\mu^2x)=\lambda\,\phi\,(\mu\,x)=\lambda^2\phi\,(x);$$
$$\phi\,(\mu^3x)=\qquad\lambda^3\phi\,(x);$$

and, in general,

$$\phi\,(\mu_n x)=\qquad\lambda^n\phi\,(x).$$

Hence, putting $x=1$, we get

$$\phi\,(\mu^n)=\qquad\lambda^n\phi\,(1).$$

Now μ is unrestricted, therefore we may put

$$z=\mu^n,\ n=\log z/\log\mu.$$

Whence, finally,

$$\phi(z) = \lambda^{\log z/\log \mu}\,\phi(1)$$
$$= z^{\log \lambda/\log \mu}\,\phi(1).$$

The general form for $\phi(z)$ is therefore

$$\phi(z) = A\,z^{B},$$

where A and B are constants, the physical meanings of which are obvious from what precedes.

We see from equation (1) that the like holds for the specific resistance of every metal which has the property indicated by the experiment.

Moreover, as you have pointed out, such a law of specific resistance is sufficient to secure the result of the experiment.

We conclude, therefore, that what the experiment really proves is that the specific resistance of metals varies as a power of the current intensity, *which power is the same for all metals.* This is a good deal, but not quite so much as is concluded in the paper in which the experiment was originally described. The deviation spoken of in the paper must therefore be regarded as deviations not from *absolutely constant resistance*, but from the *resistance calculated according to the above simple law.*

To establish that the constant B is zero will not be quite so simple a matter. Many ways might be suggested, and will, doubtless, occur to you. The most direct and satisfactory would be to get the resistance for different current-intensities, in Joule's way, by measuring the heat evolved.

Should the above sophistry be right, it is curious that you and Dr. Fison should each have suggested not *a way*, but *the only possible way*, in which the resistance may vary with the current, and Wheatstone's bridge still remain the ideal instrument that electricians have always considered it to be.

G. CHRYSTAL.

An important contribution to the theory of vacuum-tube discharges by Professor J. J. Thomson appears in the 'Phil. Mag.' for August this year. After showing experimentally that the velocity of electric transmission through electrolytes and through vacuum tubes is at least roughly the same as it is along wires, viz. the speed of light, he proceeds to consider how this is reconcilable with the doctrine of convection by moving molecules, without supposing the molecules themselves to be affected with any such extravagant velocity. He conjectures that the gas conducts by a series of Grotthus chains, of a length depending on the time of recombination of molecules; that each chain propels its own current like a series of boys on stepping-stones; and that the junctions of the chains constitute the well-known striæ.

The Committee are glad to record the appearance in English of Professor Ostwald's work, 'Outlines of General Chemistry,' wherein is given an account of the work and views of Professor van 't Hoff on solution, and the theory of electrolysis held by Dr. Arrhenius is developed into a large number of consequences. They likewise cordially welcome Professors van 't Hoff and Ostwald to England, and regret that Dr. Arrhenius has been unable to be present also.

In preparation for a discussion on the extreme dissociation theory of solution supported by these recent investigations, as opposed to the more customary view held by chemists, and having reference also to Dr. Armstrong's views of residual affinity, Professor Fitzgerald has written the following article :—

Electrolytic Theories. By Professor FITZGERALD.

Electrolysis has been explained on two different theories by Grotthus and Clausius. As generally received they differ. Grotthus' theory, as generally given, assumes that the molecules in an electrolyte are both polarised and moved by the electric forces within the liquid. This seems so far untenable that it would appear that double the electric force would double both the polarisation and the motion of the molecules, and so should produce four times the electrolysis. The objection, however, assumes that we know the causes resisting the motion, and with proper, and not very improbable assumptions as to the resistance to motion depending on it and on the polarisation, a linear relation between current and electromotive force, *i.e.* obedience to Ohm's law, seems possible. A modification of Grotthus' hypothesis in the direction of Clausius' is, however, possible. Suppose that when polarised the molecules *draw one another apart* at a rate proportional to the polarisation. This at once makes the relation between electric force and the decomposition a linear one, and so satisfied Ohm's law in the case of small currents. It also so far agrees with Clausius' hypothesis that it explains electrolysis and double decomposition as properties of the same kind. The molecules in a liquid will occasionally be arranged by accident in the proper polarised condition in a closed circuit for drawing one another apart; and if the circuit includes molecules of different kinds, there will result double decomposition. There seem to be very serious difficulties in supposing that uncombined atoms are for any finite time free in the liquid; and the supposition that it is a particular arrangement that is required before exchanges take place, and that with this arrangement exchanges take place of their own accord, seems to explain electrolysis and double decomposition without supposing free atoms to exist within the liquid. I have not assumed Professor Armstrong's suggestion that the proper arrangement for double decomposition is a double molecule; but it seems a likely hypothesis, and one that should be investigated from the chemical rather than the physical side.

There are some other phenomena that have been explained upon the supposition that free atoms are gadding about in a liquid. Such are the lowering of the boiling and freezing points by solutions of salts, and their effect on osmotic pressure. If dissociated atoms are going about in a liquid as in a gas, it seems impossible but that they must diffuse at different rates; and that this is not observed seems conclusive against the hypothesis, no matter what else the hypothesis may explain. Consider solution simply. Why does chloride of sodium dissolve in water? There must be some strong affinity between the two of a chemical or semi-chemical nature to break up the cohesion of the crystal; and it seems reasonable to assume that this same affinity keeps the molecules of NaCl moving about among the water molecules, so that they diffuse about. Now if the forces drawing them about be independent of the nature of the molecule, most of the phenomena explained by gaseous laws are explained. Pressure of a gas depends, at any temperature, on the number of molecules, and not on their kind. This is Avogadro's law, by which molecular weights are calculated; and if the forces drawing a molecule about in a liquid are independent of the kind of molecule, the very same law of pressure would hold, the pressure forward of molecules of different kinds would depend on their number only, and in the same way as Avogadro's law would enable molecular weights to be calculated. In this connection it is well to state that some bodies may be much better able to produce pressure than others, because of their being more easily polarised, *i.e.* turned into an effective direction. A molecule which could be easily turned into an effective direction would be about twice as effective as a molecule which went about in a higgledy-piggledy way; and one would consequently expect electrolytes to produce more, nearly double, the osmotic pressure that other bodies did. As to the changes of boiling and freezing points, they seem explicable by exactly the same hypothesis. The reduction of vapour pressure by molecular affinity of dissolved salt would depend only on the number of molecules of salt if all salts have the same molecular affinity for water; and the same would apply to the change in freezing point. Hence all these phenomena are explained without assuming free atoms, and they are all explained by what can hardly avoid being a *vera causa*, namely, whatever affinities they are that cause solution, which latter is an unexplained phenomenon on the dissociation hypothesis. That it is reasonable to think that the forces keeping the molecules of salt moving about in the water are independent of the nature of the salt appears from various considerations. In the first place, these forces are in all probability due to the residual affinities of the non-metallic elements. These same forces are probably the cause of crystallisation. These are old suggestions. That these residual affinities should be nearly the same for different combinations does not seem at all unlikely. If a rather shaky argument in favour of its likelihood on mechanical grounds is desired, the following may deserve attention.

Suppose a molecule of NaCl, for instance, at rest, or nearly so, in a crystal. Subject it to this affinity. Its velocity, after it has gone a distance, s, will be given by some such relation as $f s = \frac{1}{2} m v^2$. Now, for the sake of temperature equilibrium, with molecules of somewhat similar structure, $\frac{1}{2} m v^2$ must be the same in all. It seems likely that, at least approximately, the kinetic energy of motion is proportional to the total energy, and that this is the same for each molecular group; if so, the kinetic energy must be approximately the same for different groups. Now, with very dilute solutions s must be nearly the same for different molecules, and if so we get that for temperature equilibrium f must be independent of the nature of the molecule. How this equalisation of f for different kinds of molecules comes about may be as follows. Molecules in a liquid move about among one another, but are well within the sphere of another's attraction, as is evidenced by superficial tension and by the tension to which a liquid can be subject. A very small change in the distance apart of the molecules means, however, a very great change in the forces between them, as otherwise they would be extensible and compressible like gases. It seems likely, then, that when a salt dissolves in a liquid it requires for temperature equilibrium that the distances of the molecules should change by the very small amount required in order that f may become the same for all substances. This very minute change in distance would not visibly affect s.

The Committee request Mr. Shaw to continue his report on Electrolysis, with the co-operation of Mr. Fitzpatrick; and they ask for reappointment, with a grant of 5*l.* to cover printing and postage expenses.

Sixth Report of the Committee, consisting of Sir G. G. Stokes *(Chairman)*, Mr. G. J. Symons *(Secretary)*, Professor Schuster, Dr. G. Johnstone Stoney, Sir H. E. Roscoe, Captain Abney, *and* Mr. Whipple, *appointed for the purpose of considering the best methods of recording the direct Intensity of Solar Radiation.*

Owing to the death of Professor Balfour Stewart and the numerous avocations of Professor Schuster, the instrument constructed by this Committee has not yet been tried. The Committee have now traced all parts of the apparatus and of the correspondence relating to it, and they are glad to state that Professor McLeod has agreed to join the Committee and to conduct a series of experiments with the apparatus.

Report of the Committee, consisting of Dr. John Kerr *(Chairman)*, Sir William Thomson, Professor Rücker, *and* Mr. R. T. Glazebrook *(Secretary)*, *appointed to co-operate with* Dr. Kerr *in his researches on Electro-optics.*

Some progress in the experiments for the conduction of which the Committee were appointed has been made by Dr. Kerr, but the Committee regret to have to report that they are still only in the preliminary stage. The first trials were made last winter at some length, but were without effect. The difficulty arose from some unexpected and serious defects in the new plate cell, which are now being remedied.

The Committee hope that the apparatus may be in working order shortly, and look forward to being able to make a full report next year. They ask for reappointment.

Report of the Committee on Molecular Phenomena associated with the Magnetisation of Iron. (Phenomena occurring at a red heat.) Professor G. F. FITZGERALD (*Chairman*), H. F. NEWALL, F. TROUTON, *and* Professor W. F. BARRETT (*Secretary*).

IN the interim report presented last year it was stated that this Committee, which was appointed some time ago to enquire into the various molecular changes connected with the magnetisation of iron, proposed to confine itself, as we believe was the original intention on the appointment of the Committee, to those remarkable physical phenomena which are found to occur in iron and steel, about the temperature of a red heat when iron ceases to be a magnetic metal.

The suddenness with which iron loses its magnetic susceptibility at a red heat has often been noticed by different observers. Professor Rowland[1] was the first to point out that for small magnetising forces, the susceptibility of iron increases as the temperature rises, reaches a maximum at a red heat, and then falls suddenly to zero, but that the susceptibility diminishes as the temperature rises when large magnetising forces are used. Bauer[2] subsequently established the same fact. Later, one of us (H. F. Newall[3]) has experimented with small spheres of iron and steel enclosed between closely fitting hemispherical caps of brass, so that the iron sphere was held by and heated in the brass, and thus allowed to heat and cool slowly, the susceptibility being tested by means of a mirror magnetometer. It was found that during cooling from a white heat the reappearance of magnetic susceptibility was much more leisurely in steel than in soft iron, the *rate* of return to the magnetic state corresponding with the rate of recalescence; where recalescence was absent the susceptibility suddenly returned; where the reglow was pronounced the return to the magnetic state was slow. This is to be expected, for the rise of temperature during recalescence is more than sufficient to carry the iron out of the magnetic condition it had just entered upon by cooling; hence there will be a sudden oscillation at this critical temperature. Ledeboer[4] was, we believe, the first to assign the exact temperature of the loss of susceptibility. By means of a thermo-electric couple formed of wires of platinum and an alloy of platinum with 10 per cent. of rhodium, he found the susceptibility of iron to disappear at a temperature ranging from 750° to 770° C. Hopkinson[5] more recently, in his well-known paper, has investigated the effect of different magnetising forces on the loss of permeability of iron and steel with increasing temperature, more especially near the critical temperature. Measuring the resistance of copper wire (exposed to the same temperature) from its known temperature coefficient, Hopkinson estimated the temperature, and found that with very low magnetising forces, less than 1 C.G.S. unit, the permeability of *iron* gradually rose up to a temperature of 785° C., when it almost suddenly dropped down to unity; in like manner mild steel at first rose and then suddenly fell at a temperature of 735° C.: hard steel behaved similarly, falling off at a temperature of 680° C.

[1] *Phil. Mag.*, Nov. 1874.
[2] *Wied. Ann.*, xi. (1880).
[3] *Proc. Camb. Phil. Soc.*, vol. vi., Part 4 (1888).
[4] *La Lumière Electrique*, t. xxvii., No. 2.
[5] *Phil. Trans.*, May 1889.

Professor J. A. Ewing has shown recently,[1] in his beautiful experimental model representing molecular magnets, how a state of magnetic instability may occur in the magnetic metals as a certain critical temperature is approached, the chief facts of permeability and retentiveness, and what Ewing terms hysteresis, being explicable by supposing that a magnetised bar is made up, as in Weber's hypothesis, of molecular magnets, but 'constrained by no other forces than those due to their own mutual attractions and repulsions;' increase of permeability due to rise of temperature, for magnetising forces far short of saturation, being caused by the expansion and separation of molecular centres creating a reduction of stability. And as regards the sudden loss of susceptibility at the critical temperature, Ewing conjectures that the violence of the oscillation of the molecular magnets at this temperature may cause a state of rotation to be developed, wherein, of course, all magnetic polarity would disappear.

Professor Ewing's suggestive paper shows us that we may well expect other remarkable phenomena,—and abrupt changes in the physical properties of the magnetic metals *are* found to take place,—at this critical temperature. The Committee have been engaged in investigating some of these.

I. We will first take the sudden anomalous expansion observed when steel and some specimens of iron wire cool from a white heat first noticed by Gore in 1870, and the corresponding anomalous contraction on heating first noticed by one of us in 1873.[2] The observation of these effects is extremely easy. It is only necessary rigidly to fix one end of an iron or steel wire and attach the other end to a multiplying lever, or observe through a reading microscope a mark on the free end, when on heating the wire either by a gas flame or an electric current the following phenomena are observed. The wire steadily expands as the temperature rises till a low red heat is reached, when a halt occurs, then a sudden momentary retraction of the wire takes place, after which expansion continues to the fusing point. On cooling, the wire regularly contracts till a temperature a little *lower* than that at the jerk on heating is reached, when a sudden momentary elongation of the wire occurs, and then contraction ensues till it is cold. If the wire be vertical or horizontal, with or without tension, the effect is equally present. To perceive the jerk on cooling, it is, however, absolutely essential that the temperature of the wire should be raised above that at which the jerk on heating occurs, otherwise no anomalous effect is observed. In the experiments made by one of us in 1875 but not hitherto published, Barrett found that in some specimens of steel wire *two* anomalous contractions on heating and expansions on cooling were noticed, the feebler one taking place at a lower temperature. Further, that in some specimens of iron *no* anomalous expansion or contraction was noticeable, whilst more generally in other specimens the effect on *cooling only* was noticed, and that usually this effect could be wiped out by a few successive heatings and coolings. But in *steel* the jerk in cooling was always present and was not wiped out, though at first slightly reduced, by repeated incandescence and cooling. Further, judging by the amount of the expansion of the wire, the effect on heating took place, as stated above, at a slightly higher temperature than the jerk on cooling.

A series of unpublished experiments were long since made by the

[1] *Phil. Mag.*, Sept. 1890. [2] Barrett, *Phil. Mag.*, Jan. 1874.

Secretary on the effect (*a*) of the diameter of the wire, and (*b*) of the tension on the wire, the effects observed being represented by a curve where expansion is plotted against the time in seconds taken in heating and cooling. A smooth curve is, of course, formed for the non-magnetic metals. A slight break is found in the up side of the curve for fine iron wire, and a sharp break on the down side, whereas for steel-wire a sharp break on the up side, and a much more marked break on the down side, was always observed. Up to Nos. 14 or 15 B.W.G. steel-wire, *i.e.* up to a diameter of about $\frac{8}{100}$ of an inch, there is, at the critical temperature, decided retraction on heating, but at this diameter a halt, with just perceptible retraction, occurs, and as the diameter increases the halt becomes more and more prolonged, until when No. 3 wire is reached (a rod of $\frac{1}{4}$-inch diameter) at the critical temperature a halt of six seconds takes place in the expansion of the wire during heating, and a halt of twelve seconds in the contraction of the wire during cooling: the wire in all cases being *unenclosed*, and therefore freely cooling in the open air. Even with the thickest wire of a quarter of an inch diameter a slight expansion accompanies the prolonged halt in the contraction during cooling when the critical temperature is reached. Several observations, giving concordant results, were made with each wire.

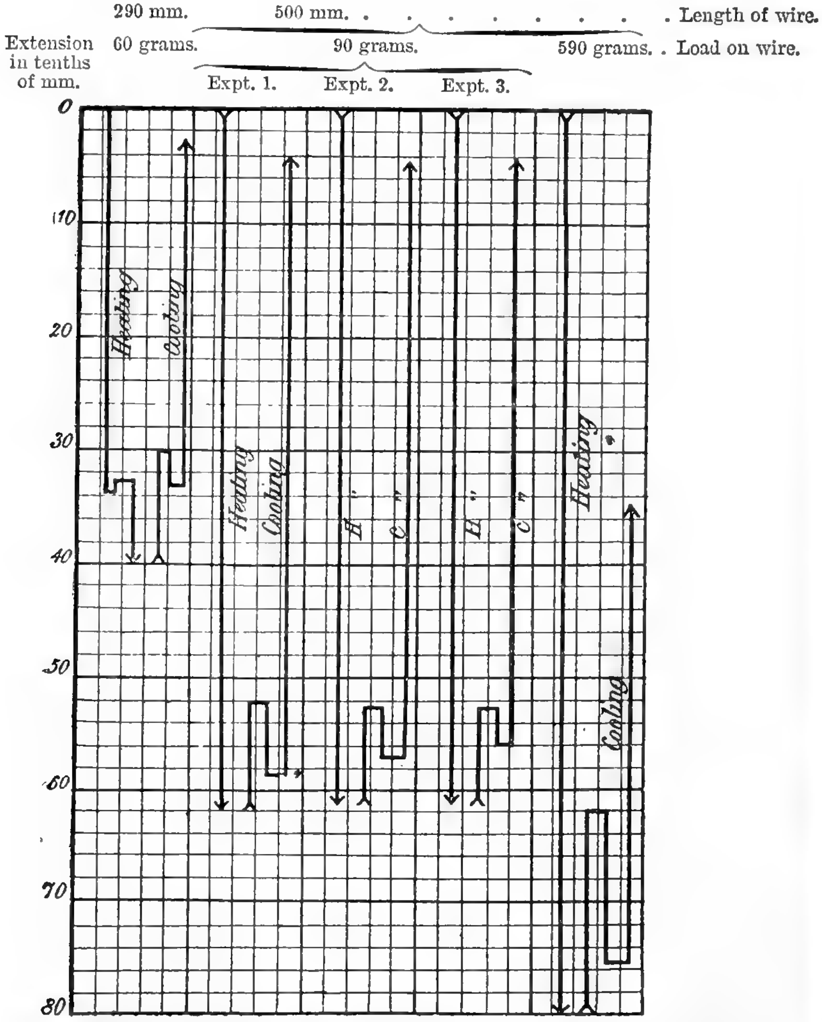
Next, as regards the effect of *tension* on the wire. As might be expected, tension has the effect of diminishing the anomalous retraction on heating and increasing the anomalous expansion on cooling. In fact, with a *soft iron* wire 20 centims. long (No. 19 B.W.G.) under a tension of 500 grams no halt is observed on heating, and at the fourth heating only a halt and no expansion on cooling; at the eighth heating the halt vanished, but a double tension, viz., 1,000 grams, caused an elongation amounting to $\frac{1}{1000}$ of the whole length of the wire to reappear. In a No. 23 *hard steel* wire, up to a tension of 500 grams, an anomalous retraction on heating and expansion on cooling is exhibited, but additional tension destroys the retraction on heating and increases the expansion on cooling. After, however, thirty re-heatings of this wire the jerk on heating had disappeared, even under the reduced tension of 300 grams, nor did sudden quenching in cold water restore it, but it reappeared in a feeble way under a tension of 50 grams; after the fiftieth re-heating all that could be observed was a momentary halt on heating, but the expansion on cooling was as marked as ever. So that even in steel the anomalous contraction on heating appears to wear out in thin wires, but not the anomalous expansion on cooling. In thicker wires of hard steel, Nos. 12, 10, 8, 7, 6, and 3, B.W.G., under tensions varying from 50 to 3,000 grams, continued heating and cooling appeared to make but little difference.[1] Here, however, the tension in grams per sq. centimetre was not so great as in the thin wire. We shall discuss later the cause of this curious wiping out of the jerk by annealing or repeated heating and cooling, and are continuing the investigation with samples of steel of known composition.

The exact amount of the retraction on heating and expansion on cooling was measured by means of a microscope with micrometer eye-

[1] It was noticed that when a flat strip of steel of the same volume as one of the thicker wires was tried, the jerk on heating vanished on repeated heating, only a momentary halt remaining, the jerk on cooling being as strong as ever; but further experiments are being made to determine how far the composition of the steel, or the effect of wire-drawing, was influential in these cases.

piece. A sample of iron-wire was taken, which was found to behave very like soft steel in the greater permanence of the effects it exhibited, and except that it could not be hardened or tempered might have been mistaken for steel; the wire was suspended vertically and heated by an electric current, a weight of 50 grams being hung from the free end. The wire was No. 20 B.W.G. (0·9 mm. diam.) and 29 centims. long. On heating it expanded from 290 mm. to 293·5 mm., or 1·2 per cent. of its length; then it retracted to 293·3 mm., a retraction of 0·07 per cent., $\frac{1}{1450}$ of its original length; then expanded again till white hot, when its length was

FIG. 1.—Anomalous contraction of Iron Wire upon cooling from a bright red heat. Wire 0·9 mm. diam.



294 mm. On breaking contact and allowing the wire to cool freely, it contracted till its length was 293 mm. or 1·034 per cent. of its length; then it expanded to 293·4 mm., an expansion of 0·14 per cent., $\frac{1}{725}$ of its length, after which it contracted till it was cold, when a permanent elongation of 0·3 mm. remained. These amounts were diminished on the second heating, but the permanent elongation, even under the small load of 50 grams, was the same each time, namely, 0·3 mm., or a little over

$\frac{1}{1000}$ of its length. Earlier experiments were made with the wire horizontal, the tension being applied by means of a pulley; the same results were obtained, but the vertical method is obviously the best. A length of 50 centims. of the same wire gave similar results, the amount of the anomalous retraction and expansion being proportional to the length of the wire. When the load was increased to 590 grams with the same wire, the retraction on heating vanished, and the sudden elongation on cooling had increased to no less than $\frac{1}{300}$ of the original length of the wire, or 0·32 per cent.: the permanent elongation being 3·5 mm. at each heating, or upwards of $\frac{1}{150}$ of the length of the wire. The diagram, Fig. 1, shows the actual change in the dimensions of the wire. It will be observed that a load of 90 grams will cause the jerk on heating to vanish with this wire, and that the jerk on cooling grows less as the experiment is repeated; at each experiment the microscope was adjusted to zero so that the total permanent elongation is the sum of that in each experiment.

II. The permanent stretching of the wire under these loads occurs only when the critical temperature is reached. At this temperature an abrupt and remarkable softening or plasticity of the iron or steel occurs which renders it extraordinarily ductile. A comparative experiment was made with copper wire heated to the same temperature. The copper wire used was 50 centims. long and rather thinner, 0·76 mm. diameter. When heated it would only bear a load of 510 grams without rupture; on heating to redness no jerk or stoppage of the expansion, and on cooling no stop in the contraction was noticed, the permanent elongation being 0·8 mm. or $\frac{1}{625}$ of the length of the wire. With the iron wire, which was considerably stouter (0·9 mm. diameter), of the same length and under the same load of 510 grams, the permanent stretching was 1·8 mm., or about $\frac{1}{280}$ of its length, so that the iron appears to be far more ductile and plastic than copper when both are at a red heat.

Mr. H. Tomlinson [1] has, in fact, already published some interesting experiments on the enormous loss of rigidity which occurs in iron at the critical temperature. A torsionally vibrating iron wire has a logarithmic decrement at about 1,000° C., ten times greater than that of a tin wire at the temperature of the air, though tin has the highest internal friction of any metal yet examined at ordinary temperatures. Mr. Tomlinson finds two temperatures, one about 550° C. and the other about 1,000° C., when there is a sudden rise in the internal friction of iron. In a series of interesting papers communicated to the Physical Society, Mr. Tomlinson has added much to our knowledge of the physical changes which occur in iron at the critical temperature. Mr. Tomlinson places near 1,000° C. the remarkable alterations he has observed in an iron wire under stress or strain. At this temperature 'when stretched by a slight weight it suddenly unstretches, when under a slight bending stress it suddenly unbends, when under a slight twisting stress it suddenly untwists, whilst on the contrary, if it has been previously bent or twisted permanently and then released from stress, it suddenly bends more or twists more as the case may be.' [2] Opposite changes occur in cooling.

One of us [3] has suggested that the probable explanation of the effects observed by Mr. Tomlinson is due to the difference in the rate of heating and cooling between the interior and exterior of the wire. Such is

[1] *Phil. Mag.*, Feb. 1888. [2] *Phil. Mag.*, Sept. 1887.
[3] Newall: *Phil. Mag.*, Nov. 1887.

doubtless the case even in thin wires, and this being so the strains in the wire will no longer be balanced if the inner and outer portion of the wire be at different temperatures. For when the wire is twisted or bent permanently, it has been submitted to a greater twisting or bending than that which it retains; a strain has been given which is larger than that which remains when the stress is removed. Now when the wire is raised to the critical temperature, the existence of this original strain reveals itself, owing to the greater plasticity of the molecules of the iron which have reached the higher temperature, and hence the additional twisting or bending which Mr. Tomlinson has observed. By keeping the wire at the critical temperature for some time, it is rendered free from strains and the effect disappears.

It is probable that the anomalous contraction and expansion in iron which we have been studying is an effect due to the longitudinal strains in the wire produced by wire-drawing, and which are destroyed by frequent heating; the non-existence or rapid subsidence of the effect in some specimens of very soft iron follows from this explanation, together with the more pronounced and enduring effects noticed in steel. Nevertheless, some other cause appears to exist in hard steel where the effect appears to be more or less permanent. We hope to throw more light on this point next year, as our experiments are being continued.[1]

During the momentary elongation of the wire at the critical temperature in cooling, a singular creaking sound is also to be observed. The sound resembles that produced by bending tin; in thick wires it more resembles a strip of tin struck on the edge by a piece of wood; it is a succession of short sounds or ticking, lasting during the anomalous change. This crepitation is evidently similar to that noticed by M. Le Chatelier at a lower temperature. It reminds one of the crepitation heard on magnetisation first noticed by Page in 1837.

III. We now come to the reglow or *Recalescence* of iron and steel at the critical temperature first noticed by Barrett ('Phil. Mag.,' 1873), and which Mons. Osmond has made the starting-point of his admirable investigations.

What is observed by the eye is as follows: The wire heated either by a current or gas flame gradually becomes luminous, then as a certain temperature is reached the glowing of the wire ceases to increase, and

[1] In a paper published in the *Comptes Rendus* for July 8, 1889, M. André Le Chatelier has shown that in the heating of iron three most remarkable phases in its mechanical properties are to be observed. In this respect it behaves differently from all other metals he has examined. From 15° to 80° C. the breaking strain, slowly applied, decreases with an increase of temperature like other metals. But from 100° to 240° C. the breaking strain is sensibly constant, and the elongation at rupture is much diminished. From 240° C. to 300° C. the breaking strain suddenly increases and the elongation also increases. From this point onwards the breaking strain decreases, but at 300° C. iron possesses its maximum strength to a *steady* strain, though it is then weakest as regards a *sudden* shock. It may here be worth noting that the temperature of 285° to 300° C. (as Mr. Tomlinson has recently observed) has a special significance in connection with the so-called Villari critical point, that is, the value of the magnetising force for which the permeability is not altered by alteration of stress on the experimental wire. This point varies both with the value of the load and the temperature of the wire. M. Le Chatelier, so far as we are aware, has not carried his investigation above 500° C., where still more interesting results may be expected. M. Le Chatelier finds that the elongation of iron under stress at about 150° C. is accompanied by a crackling sound, the lengthening not taking place continuously but in a series of jerks, a fact which he observed in upwards of 200 experiments and in all the alloys of iron.

even in some specimens a sudden darkening occurs. At this moment the anomalous contraction takes place. Heating now continues regularly till the wire reaches the melting-point. On cooling the luminosity decreases until the moment when the anomalous expansion takes place, then a sudden flash runs through the wire, first beginning at the cooler parts and suffusing the whole with a bright glow. This phenomenon of *Recalescence* is most beautifully observed by heating to whiteness with a blow-pipe flame the centre of a thin steel plate; a concentric ring of darkening will be seen to spread outward and in like manner a beautiful incandescent circle runs inward during cooling.[1] It is needless to refer to our experiments made long since, which showed that recalescence was not a mere surface effect but a rise of temperature throughout the wire, and that it occurred equally when the steel was enclosed in tubes containing pure nitrogen as well as in other gases. In some specimens of iron recalescence could not be seen, but it was present in all specimens of steel and was found whenever the jerk occurred in cooling. Numerous diagrams were also made of the duration of the after-glow in steel wires of various thicknesses.

It was noticed by one of us [2] soon after the discovery of recalescence that a faint second glow could be seen; the first and far stronger after-glow being exactly coincident with the sudden elongation of the steel wire during cooling. Thus in a No. 17 B.W.G. soft steel wire, cooling from a white heat unprotected in the air, five seconds elapsed before the first after-glow was seen and thirteen seconds before the second glow; no jerk or anomalous expansion being noticed with the second glow, but an expansion of 0·2 mm. in a wire 20 centims. long being noticed at the first glow. The same result was found with different tensions. In thicker rods of soft steel, three glows were noticed, but it is difficult to discriminate the subjective and misleading effects produced by expectant attention in the faint glows, thermometric methods alone being reliable. This has since been accomplished by Osmond, who was the first to determine the exact temperatures of recalescence in iron and steel. Continuing the early experiments, an attempt was made in 1875 by Barrett to measure the temperature of recalescence by observing the amount of expansion that occurred in the steel raised from the temperature of the air to the critical point. Assuming that the known rate of increase of the coefficient of expansion in steel with rise of temperature continued regularly, it was found that 830° C. was approximately the temperature of the critical point. The uncertainty of the data on which this estimate was founded and the difficulty of measuring these high temperatures then with any approach to accuracy, prevented the publication of a result which turns out now to be not very wide of the mark. M. Le Chatelier has lately found the coefficient of expansion for iron at 1,000° C. to be 0·0000145 for 1° C.; but measurements exactly at the critical point appear to be wanting.

We now come to M. Osmond's valuable investigations, which commenced in 1886.[3] By means of a pyrometer similar to that used by

[1] Newall: *Camb. Phil. Soc.*, January 1888.

[2] Barrett, unpublished laboratory notes, 1875.

[3] 'Transformations du Fer et du Carbone dans les Fers, les Aciers et les Fontes Blanches,' par F. Osmond, *Mémoires de l'Artillerie de la Marine.* A summary of M. Osmond's work is given in his paper read before the Iron and Steel Institute of Great Britain in the early part of the present year. M. Osmond has kindly lent us the specimens he has employed, and we hope to repeat some of his determinations shortly.

M. Ledeboer, devised by M. H. Le Chatelier, and consisting of a thermo-electric couple of platinum and platinum rhodium alloy, associated with a dead beat galvanometer, Osmond has made a careful study of the recalescence in iron and steel.

Osmond finds three critical points to exist in mild steel when, during cooling, the temperature remains stationary for a sensible interval of time. These three points he designates a_1, a_2, and a_3; a_1 being that at the lowest temperature about 660° C., a_2 about 730° C., and a_3 about 850° C. In hard steel a_1 only is present, but is much more pronounced, and occurs somewhat higher, about 700° C. In electrolytic iron, which, however, contained 0·08 per cent. of carbon, a_2 and a_3 only are present, occurring at about 720° C. and 860° C. respectively. The temperature of these critical points he finds, just as we found with the anomalous expansion and contraction, to be higher during the heating than during the cooling of the same specimen. Osmond, however, has not noticed any sudden rise of temperature at recalescence, only a longer or shorter halt in the cooling. But this difference probably arises from his mode of experimenting; one of us has pointed out the necessity of precaution in this respect.[1] We have recently repeated our experiments, using a thermo-couple similar to that employed by Osmond, and find that there is not the least difficulty in observing and measuring the sudden large *increase* of temperature that occurs during recalescence. It is only necessary to use somewhat fine wires for the thermo-couple, to bind them to the steel wire under experiment, and wrap the part round with asbestos to prevent too rapid cooling in the air.

The temperature of the critical point Osmond finds, as occurred with the jerk on heating or cooling, to be higher on the up side of the curve (that is, during heating) than on the down side of the curve. Like ourselves, he finds the critical point higher in iron than in steel, and that on re-heating the same sample the point of recalescence is lowered somewhat. Experiments we have recently made show that after the first two or three heatings stable conditions appear to be reached; recalescence then occurs at the same temperature and to the same amount on subsequent heatings and coolings. This is assuming the metal to be raised to the same temperature before cooling each time; if the temperature before cooling be not so great Osmond finds that the critical point is raised. Our experiments point rather the other way, but they need repeating. When the cooling of iron or steel is slow recalescence begins at a somewhat higher temperature, and lasts longer than when the cooling is very rapid. Osmond finds that when the cooling is very rapid, by quenching the white-hot metal in water, recalescence is entirely absent. The steel is thus hardened, and Osmond concludes that the latent heat of the change which takes place in the metal at recalescence is still in the steel, and he terms it the latent heat of hardening.

IV. The difference in the temperature at which recalescence occurs on the up and down side of the curve of heating, has led two of our Committee independently to suggest the explanation of the remarkable thermo-electric current which is produced in iron and steel by a *moving source* of heat.[2] If an iron or steel wire be heated to redness at any one point of

[1] Newall, *Phil Mag.*, June 1888.

[2] Trouton, *Proc. Royal Dublin Soc.*, 1887. Newall, *Phil. Mag.*, June 1888. Mr. Trouton has found a similar but entirely transient E.M.F., caused by a moving flame

its length, and the source of heat, such as a Bunsen flame, be moved along, an electric current is set up in the direction in which the flame travels. By means of clockwork the flame can be caused to move continuously, and hence a continuous circuit is thereby obtained. There are, however, no signs of E.M.F. in the circuit until the recalescent point is passed; then reglow takes place behind the moving flame and the cooling effect in front. This thermal difference is, we believe, the cause of the resultant E.M.F., for it ceases when the flame ceases to move, and is absent in those metals where recalescence does not occur.

V. The thermo-electric position of iron undergoes a sudden change at the critical temperature. This was first noticed by one of us in 1875; twisting a platinum wire round the iron or steel wire under experiment, and connecting the free end of the platinum and one end of the steel wire to a galvanometer, a thermo-electric current was of course observed on heating the wire, but directly the jerk occurred in heating a sudden movement of the galvanometer needle simultaneously occurred, and similarly in cooling the thermo-current changed along with the anomalous expansion, and a moment after the iron regained its magnetic susceptibility. Hot iron is thermo-electrically negative to cold iron, but at the critical point a large increase in the E.M.F. is suddenly developed. Mr. H. Tomlinson [1] has shown that iron at a bright red heat in contact with iron at the temperature of the air develops an E.M.F. of about one-twentieth of a volt, or upwards of twice that between a bismuth and antimony couple with a temperature difference of 100° C. between their junctions.

Cumming was the first to notice long ago that the thermo-electric properties of iron changed at a red heat, but to Professor Tait's classical papers on thermo-electricity we owe the first exact investigation of the changes that heat produces in the thermo-electric properties of iron. In his Rede lecture, delivered on May 23, 1873, Professor Tait remarks that when various pairs of metals were tried up to a red heat the thermo-electric diagram representing the relation of E.M.F. and temperature always exhibited an anomaly when iron was one of the metals; at some temperature near a low red heat a change occurred, the 'Thomson effect' being negative in iron at ordinary temperatures, became positive at a red heat, and remained so until a much higher temperature was reached, when another change of sign appeared to be indicated. 'Iron,' Professor Tait remarks, 'becomes as it were a different metal on being raised above a red heat; this may have some connection with the ferricum and ferrosum of the chemists, with the change of magnetic properties and of electric resistance at high temperatures.' [2]

VI. *The electric resistance* of iron at this temperature also changes; Smith, Knott, Macfarlane,[3] and more recently Hopkinson [4] and Le Chatelier,[5] have published investigations on this point. Hopkinson finds a change in the temperature coefficient of the iron wire he used at 855° C., and of hard steel wire at a somewhat lower temperature. These tempera-

to occur in other unannealed wires. This is an effect due to annealing by the flame, and disappears immediately, whereas the effect in steel is persistent.

[1] *Proc. Phys. Society*, vol. ix. p. 105 (Nov. 1887). See also on this point a paper by one of us (Newall, *Camb. Phil. Soc.*, Jan. 1888.)

[2] *Nature*, June 12, 1873. *Trans. R.S.E.*, Dec. 1873.

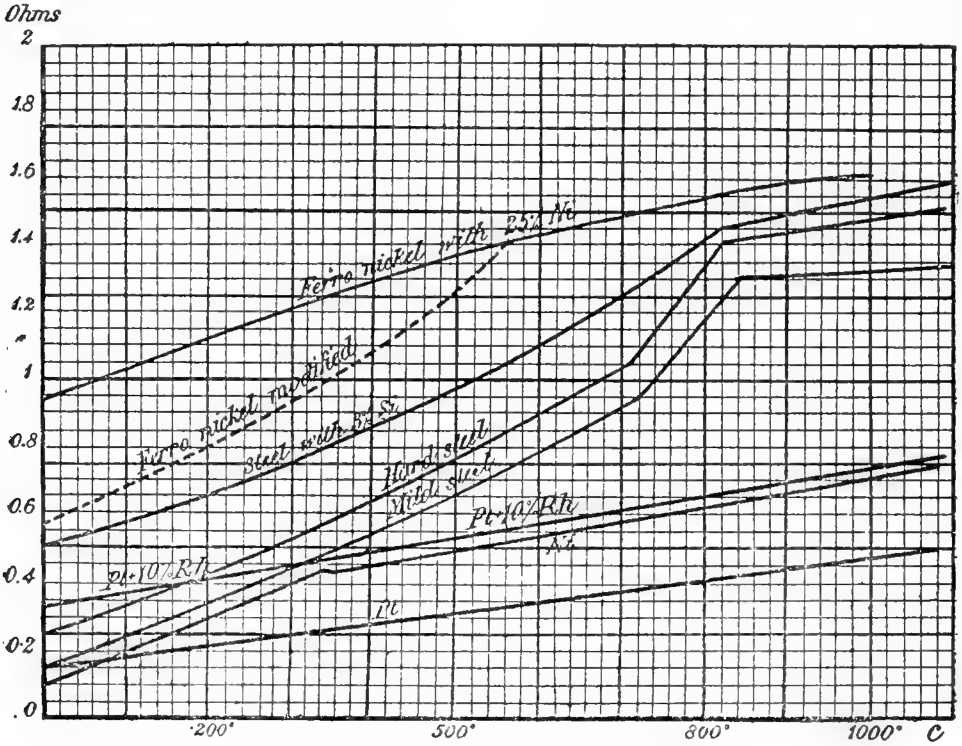
[3] *Proc. Royal Society of Edin.*, Feb. 1875.

[4] *Phil. Trans. Roy. Society of London*, May 1889.

[5] *Comptes Rendus*, Feb. 10, 1890.

tures he found practically coincident with the sudden loss of magnetic susceptibility of the metals. Le Chatelier finds mild and hard steel show two changes of curvature in their electric resistance, one at 850° C. and the other at 710° C., whereas manganese steel, in which we find recalescence to be absent,[1] shows no such change, the curve of increased resistance with temperature being perfectly regular. Le Chatelier also finds that pure nickel undergoes a sudden change in its electric resistance, the temperature coefficient altering at 340° C., which corresponds to the temperature of other changes in its physical properties.

FIG. 2.—Electric Resistance in ohms of Wires of the Metals named. 1 metre long and 1 mm. diam. heated from 0° to 1,000° C., in pure dry hydrogen (Le Chatelier).



VII. Some recent experiments made by Dr. E. Ball[2] appear to indicate that there is a still higher critical point than those observed by Osmond and ourselves. Dr. E. Ball has measured the tensile strength and roughly the magnetic state of iron and steel suddenly cooled down from different high temperatures. He finds that there are three critical points when a change in the tensile strength and magnetic character of iron and steel occur with sudden quenching; two of these points agree with Osmond's a_1 and a_3, but the third point is higher than either of these; he estimates it approximately as 1,300° C. More exact means of measuring the temperature and magnetic susceptibility are, however, necessary.

VIII. This higher temperature is near that at which M. Pionchon[3] has found a change in the *specific heat* of iron. Pionchon's results show that the specific heat of iron changes suddenly between 660° and 720° C.,

[1] Barrett, *Proc. R. Soc., Dublin*, Dec. 1886.
[2] *Proc. Iron and Steel Institute of Great Britain*, 1890.
[3] Pionchon, *Comptes Rendus*, June 1886.

and again between 1,000° and 1,050° C., considerable absorption of heat taking place at these temperatures. The lower of these temperatures corresponds with the recalescent point and loss of magnetic susceptibility in steel. Mr. H. Tomlinson, as already noticed, has also observed two critical points in iron, one about 550° C. and the other at 1,000° C.,[1] when a sudden change occurs in the viscosity of this metal. No doubt these are the same points as those observed by Pionchon, for the variable composition of the iron also, and errors in determination of these high temperatures are probably sufficient to account for the differences observed.

The *amount of heat* given out during recalescence we have estimated from the observed expansion of the metal that occurs during recalescence. Taking Pionchon's determination of the specific heat of iron at a red heat, the heat liberated in the recalescence of a specimen of iron would thus appear to be somewhat over 100 times as much as would raise the same mass of iron 1° C. Dr. Hopkinson,[2] from the length of the break in the time curve of cooling, has estimated that the heat liberated in the recalescence of hard steel is equal to 173 times that liberated when the same material falls 1° C. The amount of recalescence in hard steel, as already stated, is considerably greater than that in iron.

IX. Here it may be mentioned that the hardening of steel by sudden quenching in water cannot be produced unless the metal be raised to the temperature of recalescence.[3] Brinnell's researches have shown that the carbon in steel is in two different conditions above and below the recalescence, and by sudden quenching the so-called 'hardening carbon' is preserved in the condition in which it exists at a high temperature. At a high temperature it appears to be simply free carbon mixed with or dissolved in the iron; at the temperature of the air the researches of Müller, Abel, and Osmond and Werth, have shown that in ordinary steel carbon is combined with the iron in the form of a compound, having the definite composition Fe_3C.

X. We must now consider the general cause of these phenomena. The secretary of this Committee long since suggested it was probably to be found in the carbon present in the iron, as recalescence was most marked in those specimens of iron and steel which contained larger percentages of carbon, and this cause Osmond has now, we think, satisfactorily established.

Recalescence in *steel* Osmond attributes to the chemical combination of the iron with the carbon present in a free state, and which has been liberated by heat. Thus the point of recalescence is that at which iron carbide, Fe_3C, forms; a body which is stable at ordinary temperatures but decomposed, with absorption of heat (producing the chilling effect observed on heating) at a red heat. Now the heat of combination we find to be about 3,000 calories per gram of carbon present in the iron, as deduced from Hopkinson's estimate of the amount of heat liberated during recalescence; further experiments on this part of the subject are necessary, and we hope to make them shortly.

Recalescence in *iron* Osmond attributes to an allotropic change which he believes iron to undergo at a temperature of about 750° C. Below this temperature iron exists in one molecular state, which Osmond

[1] *Phil. Mag.*, February 1888.
[2] *Phil. Trans.*, May 1889.
[3] J. H. Brinnell, *Jernkontoret's Annalen*, 1885, and *Stahl und Eisen*, Nov. 1885. Independently observed by one of us, Newall, *Camb. Phil. Soc.*, Jan. 1888.

designates α iron; between 750° and 850° the change is in process, and above 850° C. he asserts that iron enters the other molecular state, which he designates β iron. It is, then, to the latent heat of allotropy that Osmond attributes the recalescence observed in iron, heat being absorbed to produce this change at the critical point during heating, and liberated during cooling at a somewhat lower temperature. Iron, according to this hypothesis, is a polymorphous element like sulphur, phosphorus, &c. Sudden cooling from a white heat, when the change into β iron has occurred, should tend to preserve the iron in this allotropic state; but this is not the case, except to a small extent, and hence Osmond maintains that it is the presence of carbon in the iron which keeps the iron in the β condition when suddenly cooled. Hardened steel would thus owe its properties principally to the presence of β iron, which is hard and brittle at ordinary temperature: 'both the iron and the carbon in hardened steel preserving more or less completely in the cold the condition which they possessed at a high temperature.'

We think, however, that the evidence adduced by Osmond on behalf of his theory of recalescence in iron is as yet insufficient. No doubt iron does exist in an allotropic modification at a high temperature, but the electrolytic iron with which Osmond experimented contained 0·08 per cent. of carbon, very nearly as much as some of the pure steels with which we have experimented, which contained 0·1 per cent. of carbon. It is to the influence of this small amount of carbon present in Osmond's electrolytic iron that we are inclined to attribute the feeble recalescence which he observed in his specimen. The effect, (*a*) of this residual carbon, and (*b*) of the mechanical treatment the specimen has received, such as hammering and wire-drawing, have yet to be investigated, and this we hope to undertake during the next year. If it be possible to keep iron in the β condition when cold, it should not only be hard and brittle but *non-magnetic*, and this has not yet been proved. We have made some experiments on this point by suddenly quenching at a white heat fine iron wires in cold mercury, and here will merely state that their magnetic susceptibility was not destroyed. Manganese steel, it is true, is practically non-magnetic, and this Osmond attributes to the part played by manganese in fixing the iron in the β condition, and Hopkinson has shown that whatever slight magnetic susceptibility is found in manganese steel could be accounted for by a few little bits of pure iron distributed through the mass.[1]

We believe that the difference in the temperature position of recalescence (and also of the jerk) on the up and on the down side of the curve of heating or cooling is analogous to what is found in the heating of water. In a clean vessel water may be raised above the boiling-point; suddenly at some one point steam is formed, and the whole rapidly passes into steam, the change of state being accompanied by a *fall* of temperature and large absorption of heat. Similarly steam in cooling down may be lowered below the normal point of condensation, when from some cause, such as the presence of solid particles, condensation begins and rapidly proceeds, accompanied by a *rise* of temperature.[2] The retardation of this change Mr. Tomlinson[3] considers to be due to the great internal friction which exists in iron at a red heat; in consequence of this the change takes place

[1] *Phil. Trans.*, April 1885. [2] Newall, *Camb. Phil. Soc.*, Jan. 1888.
[3] *Phil. Mag.*, Feb. 1888.

at a lower temperature than it otherwise would, until at last a sort of explosive action occurs, and the change rapidly runs throughout the whole mass, analogous to what takes place in supersaturated solutions.

This is what we may expect to occur in the magnetic metals which exhibit the phenomena of hysteresis when under stress.[1] The recent paper of Professor Ewing's on the Molecular Theory of Induced Magnetism,[2] to which we have already referred, throws remarkable light on the various phenomena we have been studying. By means of his beautiful experimental model, Professor Ewing has shown that the intermolecular magnetic forces alone are sufficient to account for the known facts of magnetisation, and that magnetic hysteresis is not due to anything in the nature of frictional resistance to the rotation of the molecular magnets, but simply to the molecular instability which results from these intermolecular magnetic actions. And, further, that the same cause explains why there is 'in magnetic metals hysteresis in physical quality generally with respect to stress, apart from the existence of magnetisation.' We shall probably have occasion in our next report to deal more fully with Ewing's explanation, and here can only congratulate the author on the value and beauty of his suggestive experiments.

Connected with this part of the inquiry, we may refer to the interesting results Hopkinson has obtained with an alloy of iron and nickel. This alloy Hopkinson finds to have two stable conditions, one being magnetic and the other non-magnetic; a high temperature destroys the magnetic state, which can only be resumed by lowering the temperature considerably below the freezing-point; the remarkable fact, now explicable by Ewing's experiments, being that this iron-nickel alloy may be either magnetic or non-magnetic at the ordinary temperature, its previous history determining the state in which it remains.[3]

Here we must leave the subject at present; we are well aware that many matters of interest have necessarily been omitted, and that we have inadequately dealt with those that have come under consideration. So many issues of importance, both to the chemist and metallurgist, as well as the physicist, have been opened up by this inquiry that we trust the Committee, which will be enlarged, may next year present a fuller report.

APPENDIX.

A proof of the foregoing report having been forwarded by us to Mons. Osmond he has sent us the accompanying notes, which we have thought desirable to add to the report:—

Page 145.—Il ne paraît pas possible que la récalescence fasse remonter la température au-dessus de $a_{c\,1.2.3}$, c'est-à-dire au-dessus du point réciproque pendant le chauffage; car, aussitôt qu'on atteint ce point réciproque, il se produit une absorption de chaleur qui doit limiter la

[1] In a paper by one of us (Newall), we pointed out some time ago that the phenomena observed in recalescence 'were really signs of something of the nature of what Professor Ewing calls hysteresis.'

[2] *Phil Mag.*, Sept. 1890.

[3] The electric resistance of this alloy at different temperatures is shown in the top curve of Fig. 2. When heated in a dry atmosphere of hydrogen the resistance regularly increases; when heated in an undried atmosphere a singular difference is observed during cooling as shown in the 'modified' curve.

récalescence. Autrement, on aurait une sorte de mouvement perpétuel. Si le retour à l'état magnétique est plus lent dans l'acier que dans le fer, c'est parceque la transformation moléculaire du fer ne se produit qu'au fur et à mesure de la combinaison du carbone, au moins dans un acier très dur.

P. 145.—Dans les expériences de Ledeboer, le couple était placé à l'extérieur du barreau et séparé de celui-ci par une lame de mica. Comme le refroidissement était rapide, je pense que le chiffre trouvé par Ledeboer (750°–770°) pour le fer est un peu bas. Hopkinson, Le Chatelier et moi sommes bien d'accord pour 850° environ. D'ailleurs, la vitesse du refroidissement peut faire varier la position du point critique de plus de 100°, comme je l'ai trouvé dans des expériences inédites.

P. 146 (*en bas*).—La disparition de certains effets après un petit nombre de réchauffages me paraît un phénomène curieux et qui demande à être étudié complètement. Il s'agit peut-être de la destruction de l'action d'un écrouissage antérieur ?

P. 147.—J'ai fait des expériences pour déterminer le rôle de la tension dans la position des points critiques. Dans ma pensée, il est hors de doute que la traction ou la compression doivent déplacer les points critiques, comme cela a été prouvé expérimentalement pour l'iodure d'argent par Mallard et H. Le Chatelier. Cependant, les résultats de mes expériences sont restés douteux et je ne les ai pas publiés ; mais, comme j'opérais par traction et qu'une tige de fer au rouge ne peut supporter qu'une charge extrêmement faible, il n'est pas étonnant que l'effet dû à la tension soit resté dans la limite des erreurs d'expérience. J'ai l'intention de reprendre ces expériences si je puis le faire dans de meilleures conditions.

P. 149.—Les températures de 1,000° et de 550° données par Mr. Tomlinson ne sont guère d'accord avec l'ensemble des autres observations. Il y aurait lieu de reprendre ces expériences de façon à pouvoir rattacher les phénomènes observés par Tomlinson à d'autres phénomènes dont la position soit bien connue. Vers 1,000°, ou à une température supérieure, il se produit un maximum d'accélération dans la transformation du grain et il peut en résulter un changement correspondant dans la rigidité. A mon avis, ces phénomènes se rattachent au point de fusion de la fonte blanche, une fusion locale pouvant alors se produire aux points les plus carburés. Mais, avant de discuter, il faudrait d'abord être sûr que les températures données par Tomlinson sont bien exactes. Celle de 550° surtout ne répond à rien de connu, à moins qu'il ne s'agisse d'acier au tungstène.

P. 150.—Les effets de contraction et de dilatation anormales observés sont dus *en partie* à l'élévation de température pendant le refroidissement et au phénomène inverse pendant le chauffage. Ces effets sont donc permanents pour l'acier, quelque soit la nombre des chauffages successifs, pourvu que la perte de carbone ne soit pas trop forte. Dans le fer doux, au contraire, cette cause de contraction ou de dilatation est moindre, puisque la récalescence proprement dite est faible ou nulle. On comprend alors que l'effet disparaisse par les chauffages répétés, s'il est dû en partie à l'écrouissage antérieur. (*Confer* Norris.) Le fer écroui est *moins* dense que le fer recuit ; il est donc naturel que, au point critique pendant le chauffage, le fil se raccourcisse la première fois qu'on le chauffe et que ce phénomène ne se reproduise plus ultérieurement. Dans l'acier, il y a plusieurs phénomènes superposés.

P. 152.—J'ai observé très souvent l'élévation de température qui correspond à la récalescence. Je ne nie pas d'ailleurs l'influence de la grosseur des fils; mais, en dehors de cela, puisque j'opérais toujours avec les mêmes fils, il y a tantôt élévation de température, tantôt simple station pour le même métal au gré de causes encore obscures. Je ne crois pas qu'il y ait lieu d'attacher beaucoup d'importance à cette différence.

P. 152.—Dans certaines de mes expériences, l'influence de la température initiale du refroidissement a pu se confondre avec celle des refroidissements successifs; il y aurait lieu de faire séparément la part des deux influences. Je suis d'accord avec la commission pour dire que, après deux ou trois chauffages, généralement dès le second chaffauge, la position des points critiques tend à devenir sensiblement fixe. Il est possible que j'aie attribué à tort à la température initiale du refroidissement l'abaissement qui était dû aux réchauffages successifs; cependant, Hopkinson signale le même fait. C'est à vérifier.

P. 152, IV.—L'explication est en effet très satisfaisante et même certaine. H. Le Chatelier a fait une pile sur le même principe en employant l'acier-nickel pour lequel l'écart est beaucoup plus grand entre les points réciproques pendant le chauffage et le refroidissement.

P. 154, VII.—Voir mes observations à propos de la communication de Ball, 'Journal of the Iron and Steel Institute,' année 1890, p. 102.

Pp. 154, 155, VIII.—L'absorption de chaleur signalée par Pionchon entre 1,000° et 1,050° n'existe pas dans cette région, mais bien, selon moi, à 860°, température qui peut s'élever jusqu'à 900° environ selon la vitesse du chauffage et la composition du métal; la méthode de Pionchon présente de grandes difficultés d'application qui n'existent pas dans la méthode du refroidissement; s'il y avait une évolution de chaleur notable entre 1,000° et 1,050°, mes courbes le montreraient indubitablement. Il convient toutefois d'observer que l'absorption pendant le chauffage paraît être beaucoup plus progressive que le dégagement inverse pendant le refroidissement: il résulte de là que les limites du phénomène manquent de netteté.

P. 155, VIII.—Je crois que Hopkinson a estimé trop haut la quantité de chaleur dégagée en $a_{r.3}$ parcequ'il était trop près du point mort entre le chauffage et le refroidissement, c'est-à-dire dans une période où le refroidissement n'avait pas encore pris son allure régulière.

P. 155, X.—Je suis très heureux de voir mes conclusions sur ce point acceptées par la commission. On peut se faire une idée de la quantité de chaleur dégagée par la combinaison de 1 gr. de carbone avec le fer en partant de mes expériences calorimétriques. ('Théorie cellulaire,' p. 36 et suiv.) Ces expériences conduiraient à un chiffre très notablement supérieur à 3,000 Unités, et qui pourrait atteindre 8,000 Unités au maximum, chiffre analogue à celui de la combinaison du carbone avec l'oxygène. Je ne puis d'ailleurs donner un chiffre exact, ne possédant qu'une seule équation pour déterminer plusieurs inconnues.

P. 156.—Je compte publier prochainement quelques observations nouvelles à l'appui de ma théorie et discuter à ce point de vue l'objection de Howe, qui me paraît, en réalité, être plutôt favorable que contraire à mes idées. Si le fer doux trempé reste magnétique, c'est qu'il est théoriquement et pratiquement impossible de maintenir la totalité du fer à l'état β pendant le refroidissement brusque. Mais il serait facile de constater, sur le fer le plus doux, que la trempe diminue le magnétisme total à saturation et augmente la force coercitive. C'est là tout ce que l'on peut obtenir, mais ce sera suffisant. Si rapide que soit le refroidissement, le fer reste dans la région où la transformation moléculaire est possible pendant un temps qui n'est jamais nul.

P. 156 (*en bas*).—Ces considérations et celles de Mr. Tomlinson sont analogues à celles que j'ai rapidement indiquées de mon côté et me paraissent justes.

Tenth Report of the Committee, consisting of Sir WILLIAM THOMSON, Mr. R. ETHERIDGE, Professor JOHN PERRY, Dr. HENRY WOODWARD, Professor THOMAS GRAY, *and* Professor JOHN MILNE (*Secretary*), *appointed for the purpose of investigating the Earthquake and Volcanic Phenomena of Japan. (Drawn up by the Secretary.)*

IN consequence of the Secretary's absence from Japan during the greater portion of the past year, the opportunities for original investigation have not been so great as in previous years.

THE GRAY-MILNE SEISMOGRAPH.

The first of the Gray-Milne seismographs constructed in 1883, partly at the expense of the British Association, still continues to be used as the standard instrument. The earthquakes which it has recorded since March 4 of last year are given in the following list.

Catalogue of Earthquakes recorded at the Meteorological Observatory, Tokio, between March 18, 1889, *and April* 27, 1890, *by the Gray-Milne Seismograph.*

No.	Month	Date	Time	Duration	Direction	Period in seconds	Double Amplitude in mm.
			1889.				
			H. M. S.	M. S.			
905	III.	18	6 41 12 A.M.	—	N.-S.	—	—
906	,,	21	6 9 23 P.M.	—	—	—	—
907	,,	26	2 41 48 P.M.	—	—	—	—
908	,,	28	1 20 40 A.M.	1 30	E.S.E.-W.N.W.	0·6	4·1
				vertical	motion	0·5	0·6
909	,,	,,	10 22 55 A.M.	1 15	S.E.-N.W.	0·5	0·5
				vertical	motion	0·4	0·1
910	,,	,,	9 18 23 A.M.	0 20	E.-W.	0·2	0·2
911	,,	31	6 42 15 A.M.	4 0	S.S.E.-N.W.	2·5	3·8
				vertical	motion	0·6	0·2
912	,,	,,	8 13 3 A.M.	—	—	very	slight
913	,,	,,	5 59 42 P.M.	2 0	S.W.-N.E.	0·7	1·2
				vertical	motion	very	slight
914	IV.	3	4 27 21 P.M.	1 30	S.E.-N.W.	0·7	1·5
				vertical	motion	0·3	0·2
915	,,	,,	4 40 51 P.M.	—	—	very	slight
916	,,	6	7 40 13 A.M.	0 50	S.W.-N.E.	0·5	0·3
				vertical	motion	very	slight
917	,,	8	0 48 0 P.M.	—	—	very	slight
918	,,	14	5 22 54 A.M.	—	—	very	slight
919	,,	17	9 41 43 P.M.	—	—	very	slight
920	,,	18	2 7 42 P.M.	—	E.S.E.-W.N.W.	1·0	0·8
				vertical	motion	0·7	0·2
921	,,	,,	2 54 11 P.M.	—	—	very	slight
922	,,	,,	3 39 8 P.M.	—	S.E.-N.W.	0·9	0·3
923	,,	,,	4 0 1 P.M.	—	—	very	slight

No.	Month	Date	Time	Duration	Direction	Period in seconds	Double Amplitude in mm.
924	IV.	19	0 18 46 A.M.	—	—	very slight	
925	”	”	2 29 19 A.M.	—	—	very slight	
926	”	29	3 0 27 P.M.	0 50	S.W.–N.E.	0·6	0·2
927	”	”	5 50 39 P.M.	1 30	E.–W.	0·6	0·2
928	”	”	10 53 55 P.M.	—	—	very slight	
929	”	20	4 50 33 P.M.	—	—	very slight	
930	”	28	3 7 43 A.M.	0 30	E.–W.	slight	
				vertical motion		slight	
931	”	29	1 56 28 A.M.	0 20	E.–W.	slight	
				vertical motion		very slight	
932	V.	6	11 41 41 P.M.	1 0	S.S.W.–N.N.E.	0·5	0·4
				vertical motion		very slight	
933	”	8	5 5 34 A.M.	0 30	S.–N.	slight	
				vertical motion		slight	
934	”	”	0 24 7 P.M.	—	—	very slight	
935	”	12	10 42 11 A.M.	2 0	S.S.E.–N.N.W.	2·0	0·6
936	”	17	6 39 15 A.M.	—	—	very slight	
937	”	”	8 34 25 A.M.	—	—	very slight	
938	”	”	9 20 35 A.M.	—	—	very slight	
939	”	”	9 39 37 A.M.	—	—	very slight	
940	”	”	1 46 32 P.M.	0 30	—	slight	
941	”	20	0 23 30 P.M.	—	—	very slight	
942	”	27	6 22 56 P.M.	0 12	E.–W.	very slight	
943	”	28	5 26 22 A.M.	0 15	E.–W.	slight	
944	”	30	10 27 22 A.M.	2 0	S.E.–N.W.	0·8	0·4
945	VI.	1	6 15 21 A.M.	0 25	E.–W.	0·5	0·2
946	”	3	1 51 30 P.M.	—	—	slight	
947	”	14	0 26 41 P.M.	—	—	slight	
948	”	15	10 10 2 A.M.	0 50	—	slight	
949	”	16	2 31 24 P.M.	0 30	S.E.–N.W.	slight	
950	”	20	9 51 10 P.M.	1 30	S.E.–N.W.	0·6	0·5
951	”	27	7 9 17 A.M.	1 0	E.–W.	2·5	0·5
952	VII.	2	5 39 58 A.M.	0 40	E.–W.	0·5	0·3
				vertical motion		very slight	
953	”	5	6 22 31 P.M.	—	—	very slight	
954	”	”	8 57 9 P.M.	—	—	very slight	
955	”	18	10 33 18 P.M.	0 35	S.–N.	slight	
956	”	30	2 3 40 A.M.	0 10	E.–W.	slight	
957	VIII.	2	10 21 6 A.M.	1 30	S.E.–N.W.	0·5	1·3
				vertical motion		0·3	0·4
958	”	4	2 36 12 P.M.	—	—	very slight	
959	”	5	7 4 56 A.M.	4 20	E.S.E.–W.N.W.	1·1	1·7
960	”	15	0 6 21 P.M.	—	—	slight	
961	”	20	5 20 23 P.M.	0 50	N.–S.	0·8	0·3
962	”	21	1 7 44 P.M.	—	—	slight	
963	”	26	3 27 13 P.M.	1 0	E.–W.	0·6	1·4
				vertical motion		0·4	0·2
964	”	30	3 6 22 P.M.	3 30	E.S.E.–W.N.W.	1·0	0·4
965	IX.	11	7 14 3 P.M.	—	—	slight	
966	”	15	2 34 6 A.M.	—	—	slight	
967	”	16	6 37 30 A.M.	1 30	W.S.W.–E.N.E.	0·7	1·3
				vertical motion		slight	
968	”	17	2 4 28 A.M.	—	—	very slight	
969	”	20	10 27 1 A.M.	—	—	slight	
970	”	22	1 56 33 A.M.	—	—	very slight	
971	”	30	7 41 27 A.M.	—	—	very slight	
972	X.	1	6 7 20 A.M.	—	—	very slight	
973	”	7	7 41 18 P.M.	—	—	very slight	
974	”	10	6 47 27 A.M.	—	—	slight	
975	”	13	10 50 24 P.M.	2 0	S.E.–N.W.	2·0	2·2
				vertical motion		0·6	0·4
976	”	14	11 8 10 P.M.	1 0	E.–W.	0·4	0·2
977	”	16	4 10 48 P.M.	—	—	very slight	
978	”	25	11 16 3 A.M.	—	—	very slight	
979	”	28	2 16 52 A.M.	2 0	S.E.–N.W.	0·9	1·2
				vertical motion		slight	
980	XI.	14	0 30 50 P.M.	—	—	very slight	
981	”	15	8 48 40 P.M.	—	—	slight	
982	”	17	1 57 56 P.M.	—	—	slight	
983	”	18	8 31 39 A.M.	—	—	slight	
984	”	”	1 35 1 P.M.	—	—	very slight	
985	”	20	0 56 34 A.M.	0 50	N.–S.	0·9	0·2
986	”	21	2 5 32 A.M.	0 30	S.E.–N.W.	0·6	0·2
987	”	”	1 50 5 P.M.	2 30	—	slight	
988	”	25	2 34 8 A.M.	0 16	N.E.–S.W.	0·5	0·3
989	XII.	9	0 3 14 P.M.	0 15	—	slight	
990	”	11	5 14 17 A.M.	—	—	very slight	

No.	Month	Date	Time	Duration	Direction	Period in seconds	Double Amplitude in mm.
991	XII.	26	8 14 11 P.M.	—	—		very slight
992	„	28	10 17 58 P.M.	1 5	E.–W.	0·3	0·5
993	„	29	11 10 19 A.M.	—	—		slight
994	„	31	1 5 13 P.M.	5 20	E.S.E.–W.N.W.	2·8	2·1
				vertical motion			slight
				1890.			
995	I.	7	7 47 37 A.M.	0 40	S.–N.		slight
996	„	„	3 43 25 P.M.	5 0	S.E.–N.W.	3·0	2·0
997	„	12	4 15 33 A.M.	—	—		very slight
998	„	29	11 28 3 P.M.	0 57	E.–W.	0·7	0·3
999	„	30	8 35 31 A.M.	—	—		very slight
1,000	II.	13	9 48 16 P.M.	0 30	E.–W.	0·2	0·2
1,001	„	18	5 31 10 A.M.	—	—		slight
1,002	„	„	9 50 6 A.M.	—	—		slight
1,003	„	21	2 44 13 A.M.	0 40	E.–W.		slight
1,004	„	24	0 47 2 A.M.	0 30	S.E.–N.W.	0·8	0·2
1,005	III.	7	4 21 42 A.M.	0 20	E.–W.	0·4	0·2
1,006	„	11	11 7 2 A.M.	0 30	—		slight
1,007	„	„	7 53 49 P.M.	1 0	E.S.E.–W.N.W.	0·2	0·4
1,008	„	18	3 16 4 P.M.	0 20	—	—	slight
1,009	„	26	6 57 55 A.M.	—	—	—	slight
1,010	„	28	2 22 37 P.M.	—	—	—	slight
1,011	IV.	5	0 20 0 P.M.	—	—	—	slight
1,012	„	11	3 8 2 A.M.	1 5	E.–W.	0·9	0·4
1,013	„	16	9 34 47 P.M.	7 0	S.E.–N.W.	2·9	22·4
				vertical motion		0·6	0·2
1,014	„	„	11 40 3 P.M.	—	—		slight
1,015	„	17	4 56 45 A.M.	8 0	S.E.–N.W.	3·8	7·8
				vertical motion			slight
1,016	„	„	5 11 3 A.M.	—	—		slight
1,017	„	„	6 42 36 A.M.	6 30	S.E.–N.W.	3·4	3·3
1,018	„	„	3 31 38 P.M.	—	—		slight
1,019	„	„	10 25 15 P.M.	3 30	S.E.–N.W.	2·5	1·2
1,020	„	18	5 38 37 P.M.	—	—		slight
1,021	„	„	7 15 57 P.M.	—	—		slight
1,022	„	„	11 3 0 P.M.	—	—		slight
1,023	„	19	9 45 52 A.M.	—	—		slight
1,024	„	„	1 7 37 P.M.	—	—		slight
1,025	„	27	8 36 48 P.M.	—	—		slight

In the preceding list the most remarkable earthquakes which I had the opportunity of observing were the series commencing on April 16, 1890, at 9h. 34m. 47s. P.M. This disturbance was felt along the eastern coast of Japan from lat. 38°N to the bay of Owari in the south—a distance of about 300 miles. It extended inland across the backbone of the country as far as Nagano. The land area shaken was 4,743 square ri (1 sq. ri = 5·9 sq. miles). The origin appears to have been to the west of Miyakijima, where about 70 shocks were felt and buildings damaged, about 100 miles S.S.W. from Tokio in the Pacific Ocean. The period of the large waves was nearly 3 seconds and the duration 7 minutes. After sensible motion had ceased, which lasted from 2 to 3 minutes, I was standing watching one of my seismographs, which every few seconds gave fitful movements, some of which were large enough to swing the pointers off the recording surface. These movements were far too slow to suppose them to be in any way connected with the inertia of the heavy masses constituting the bobs of the horizontal pendulums. In my opinion the movements were not due to sudden horizontal impulses, but to gentle and irregular tiltings of the instrument. It was in fact as if we were on a huge raft, beneath which waves of a very long period were passing. No movement could be felt.

The earthquake at 4h. 56m. 45s. A.M. next morning lasted *eight minutes*, and had a period of nearly 4 seconds. It shook 3,533 square ri, but only extended to lat. 37°N.

The one at 6h. 42m. 36s. A.M., which lasted 6½ minutes, and had a period of 3·4 seconds, extended to lat. 36°N., and shook 2,236 square ri. All these disturbances extended southwards to Owari.

The Kumamoto Earthquake.

During my absence in Europe, on July 28, 1889, at 11h. 40m. P.M., the whole of Kiushiu, a portion of Shikoku, and the main island were disturbed by an earthquake of unusual severity. The land area shaken was 6,520 square ri, the most violent motion being on the western flanks of the volcano Mount Aso, which has a well-formed ring crater 7 to 12 miles in diameter, with a smoking cone in the centre.

Altogether some 114 shocks were felt, and subterranean roarings were heard 87 times. These disturbances occurred between July 28 and August 13. The damage may be summed up as follows:—

Houses ruined	200	Persons injured	74
Houses shattered	200	Bridges destroyed	19
Persons killed	20	Bridges broken	21

At Oita, some 60 miles north of the district of greatest disturbance, a seismograph gave the following records:—

Duration	70 secs.
Direction	S.S.W.–N.N.E.
Maximum horizontal motion	12·4 mm.
Period	2·7 secs.

The movement was gentle.

Earthquakes in 1887.

In my fourth report to the British Association, I gave an account of 387 earthquakes which had occurred in North Japan between October 1881, and October 1883. In consequence of this work, the expenses of which were partly defrayed by this Association, Mr. Arai Ikunosake, director of the Meteorological Department, established some 600 post-card stations throughout the empire with a view of making similar but more extended observations. The results of these observations for 1886 were given in my eighth report, and the following is an epitome of the results obtained for 1887. For purposes of comparison these latter have been combined with the results for 1885 and 1886.

Frequency of Earthquakes.

During the years 1885, 1886, and 1887, the numbers of earthquakes recorded in Japan were 482, 472, and 483, the numbers representing the daily average of shocks per day being 1·32, 1·29, and 1·32. The greatest number of shakings in 1887 occurred near Tokio, where 80 distinct shocks were recorded, and some 30 or 40 miles to the north of Tokio, in Shilachi, where 50 disturbances were noted.

Distribution of Seismic Energy.

Speaking generally, the areas which are most frequently shaken are the same in successive years, the eastern side of the country being very much more disturbed than the western side. If we take a map of Japan, and commence at the north-eastern end of Yezo, and proceed southwards along the Pacific Coast, the districts most disturbed are, with but three exceptions, the extremities of all the peninsulas jutting out into the ocean —a fact which, when we remember that many of these peninsulas represent earth-foldings which may be continued, or are being continued, beneath the ocean, is of considerable significance. The exceptions referred to are the earthquakes of the alluvial plain round, and to the north of Tokio—where at least 80 shocks were recorded—the earthquakes on the alluvial plain at the head of the Bay of Owari, and the earthquakes round the flat shores of the Bay of Tosa, on the south side of Shikoku.

During 1887 the Shinano earthquakes, which in 1886 were 19 in number, decreased to 5, whilst the Echigo disturbances decreased from 31 to 10. These localities are inland, and are respectively at distances of 60 miles N.E. of Tokio and 100 miles north of Tokio.

As in previous years, in Central Japan, where there are many earthquakes and many volcanoes, the earthquakes, or at least the majority of them, did not come from the volcanoes. In the Kü peninsula, where there are no volcanoes, there have been many earthquakes; but there are also districts, as for example the southern extremity of Kiushiu, where there have been a fair number of earthquakes, where it is possible that such disturbances may be directly connected with the proximity of volcanoes. On the whole, however, there is no reason to consider that the majority of earthquakes are in any way connected with volcanoes. The approximate origin of shocks which have been recorded in 1886 and 1887 is given in the following table, from which we see, at least for 1887, that the greater number of earthquakes, especially those of any extent, have chiefly originated along the coast or beneath the sea.

Table of distribution of earthquake origins relative to sea and land.

—		Total	Large	Moderate	Small
Earthquakes which occurred beneath the sea or along the coast.	1886 1887	228 302	15 36	50 76	163 190
Earthquakes which occurred inland	1886 1887	244 181	11 14	70 34	163 133
Total number	1886 1887	472 483	26 50	120 110	326 323
More (+) Less (−) for 1887 . . .	+	+11	+24	−10	−3

Areas Shaken by Earthquakes.

Probably the best method we have at our command for measuring the seismic activity of any region, rather than considering it proportional to the number of disturbances which occur, is to measure it by the area of land which has been shaken. As has been pointed out in the Report for 1888, this method of measuring intensity is only approximate, but still it is very much better than methods used by previous investigators. The unit is one square ri or 5·95 square miles.

Table shewing Total Areas—in sq. ri—of shaken districts for the years 1885, 1886, 1887, *arranged according to months.*

—	Jan.	Feb.	Mar.	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Total	Average
1885	10,020	16,980	7,320	4,750	10,380	15,890	9,170	6,060	14,570	21,340	4,120	11,700	132,300	11,025
1886	3,240	5,550	4,810	12,480	15,380	5,080	10,490	10,820	9,500	3,860	2,480	8,360	92,050	7,671
1887	23,200	16,270	3,200	12,310	13,220	5,920	13,290	7,820	14,580	2,680	11,950	9,390	133,830	11,152
Average 1885–1887	12,153	12,933	5,100	9,847	12,993	8,963	10,983	8,233	12,883	9,293	6,183	9,817	119,391	9,949
Average 1885–1886	6,630	11,265	6,065	8,615	12,880	10,485	9,830	8,440	12,035	12,600	3,300	10,030	112,175	9,348
Total areas for 1887, larger (+) or smaller (−) than the average for 1885, 1886	+16,570	+5,005	−2,865	+3,695	+340	−4,565	+3,460	−620	+2,544	−9,920	+8,650	−640	+21,655	+1,805

Table shewing Average Areas—in sq. ri—of shaken districts for 1885, 1886, 1887, *arranged according to months.*

—	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
1885	310	390	200	130	200	370	290	210	320	520	80	290
1886	80	140	100	330	260	170	290	230	230	120	110	200
1887	570	280	110	420	220	160	350	220	340	130	340	170
Average 1885, 1886, 1887	320	270	137	293	227	233	310	220	297	257	177	220
Average 1885, 1886	195	265	150	230	230	270	290	220	275	320	95	245
Average areas, 1887, larger (+), smaller (−), than average for 1885, 1886	+375	+15	−40	+190	−10	−110	+60	—	+65	−190	+245	−75

Table of the Earthquakes for each month of the years 1885, 1886, 1887. *Arranged according to the area of shaken districts.* (1 *sq. ri* = 5·95 *sq. miles.*)

Square Ri	Year	Jan.	Feb.	Mar	Apl.	May	Jne.	Jly.	Aug	Sep.	Oct.	Nov	Dec.	Total	Avrge
	1885	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Above 7,000	1886	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	1887	—	—	—	1	—	—	—	—	—	—	—	—	1	·08
	1885	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6,000 to 7,000	1886	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	1887	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	1885	—	1	—	—	—	—	—	—	—	1	—	—	2	·16
5,000 to 6,000	1886	—	—	—	—	—	—	1	—	—	—	—	—	1	·08
	1887	1	1	—	—	—	—	—	—	—	—	—	—	2	·16
	1885	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4,000 to 5,000	1886	—	—	—	1	—	—	—	—	—	—	—	—	1	·08
	1887	1	—	—	—	1	—	1	—	1	—	—	—	4	·3
	1885	—	—	1	—	1	1	1	—	1	1	—	—	6	·5
3,000 to 4,000	1886	—	—	—	—	1	—	1	1	—	—	—	—	3	·25
	1887	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	1885	1	2	—	—	1	2	1	—	3	1	—	2	13	1·1
2,000 to 3,000	1886	—	—	—	1	2	—	—	1	1	—	—	—	5	·4
	1887	3	—	—	—	—	—	1	1	—	—	1	1	7	·6
	1885	—	1	—	1	—	1	—	1	—	4	—	1	9	·8
1,000 to 2,000	1886	—	1	—	1	1	1	—	—	3	—	1	1	9	8·
	1887	2	4	—	2	1	1	2	2	3	—	4	2	23	1·9
Total	1885–86	1	5	1	4	6	5	4	3	8	7	1	4	49	4·1
Average	1885–86	—	2	—	2	3	2	2	1	4	3	—	2	21	1·7
Total	1887	7	5	—	3	2	1	4	3	4	—	5	3	37	3·1
No. in 1887 above (+) or below (−) the average for 1885–86	—	+7	+3	—	+1	−1	−1	+2	+2	—	−3	+5	+1	+16	+1·4
	1885	2	1	1	—	—	2	1	1	2	—	—	2	12	1·
750 to 1,000	1886	—	1	2	1	2	1	—	2	—	1	—	2	12	1·
	1887	1	1	—	—	1	1	1	1	2	1	—	—	9	·8
	1885	5	4	1	1	—	1	—	2	1	2	—	—	17	1·4
500 to 750	1886	1	1	—	2	—	—	—	1	2	2	—	4	13	1·1
	1887	—	2	1	—	6	1	1	—	1	1	3	2	18	1·5
	1885	2	1	—	2	4	1	2	1	—	6	1	4	24	2·
300 to 500	1886	2	2	2	1	3	4	1	1	—	2	1	1	20	1·7
	1887	2	4	4	2	1	3	2	1	3	1	—	2	25	2·1
	1885	—	1	2	1	1	4	—	4	1	2	9	2	27	2·2
200 to 300	1886	2	—	4	1	4	2	2	2	1	—	—	2	20	1·7
	1887	2	2	—	1	2	2	1	2	2	1	2	4	21	1·7
	1885	3	6	5	6	16	7	4	2	4	—	5	5	63	5·2
100 to 200	1886	5	3	2	3	4	4	1	5	4	3	1	4	39	3·2
	1887	3	1	2	3	4	2	2	—	2	2	1	2	24	2·
Total	1885–86	22	20	19	18	34	26	11	21	15	18	17	26	247	20·5
Average	1885–86	11	10	9	9	17	13	5	10	7	9	8	13	121	10·1
Total	1887	8	10	7	6	14	9	7	4	10	6	6	10	97	8·1
No. in 1887 above (+) or below (−) the average for 1885–86	—	−3	—	−2	−3	−3	−4	+2	−6	+3	−3	−2	−3	−24	−2·
	1885	19	27	27	26	28	27	23	19	33	24	32	24	309	25·7
Below 100	1886	28	31	39	27	41	18	30	33	30	25	19	28	349	29·1
	1887	26	43	23	20	44	28	27	28	29	14	24	43	349	29·1
Total	1885–86	47	58	66	53	69	45	53	52	63	49	51	52	658	54·8
Average	1885–86	23	29	33	26	34	22	26	26	31	24	25	26	325	27·1
No. in 1887 above (+) or below (−) the average for 1885–86	—	+3	+14	−10	−6	+10	+6	+1	+2	−2	−10	−1	+17	+24	+2·
Total No.	1885–86	70	83	86	75	109	76	68	76	86	74	69	82	954	79·5
Average No.	1885–86	35	41	43	37	54	38	34	38	43	37	34	41	475	39·6
Total No.	1887	41	58	30	29	60	38	38	35	43	20	35	56	483	40·2
No. in 1887 above (+) or below (−) the average for 1885–86	—	+6	+17	−13	−8	+6	—	+4	−3	—	−17	+1	+15	+8	10·7

From the above tables we learn that in 1885, 1886, and 1887, land areas were shaken which were respectively 5·4, 3·8, and 5·5 times the area of the whole empire.

Distribution of Earthquakes in Time.

The following table gives the number of earthquakes for 1885, 1886, 1887, arranged according to months:—

—	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Aver.
1885	32	44	37	37	51	46	32	30	45	41	47	40	482	40·2
1886	38	39	49	38	58	30	36	46	41	33	22	42	472	39·3
1887	41	58	30	29	50	38	38	35	43	20	35	56	483	40·2
Average 1885, 1886, 1887	37·0	47·0	38·7	34·7	56·3	38·0	35·3	37·0	43·0	31·3	34·7	46·0	479·0	39·92
Average 1885, 1886	35	41	43	37	54	38	34	38	43	37	34	41	475	39·6
No. of Earthquakes in 1887 above (+) or below (−) the average for 1885, 1886	+6	+17	−13	−8	+6	—	+4	−3	—	−17	+1	+15	+8	+0·7

The number of earthquakes for 1885, 1886, 1887, arranged according to the four seasons, is as follows:—

—	Spring	Summer	Autumn	Winter	Total	Average
1885	125	108	133	116	482	120·5
1886	145	112	96	119	472	118·
1887	119	111	98	155	483	120·7
Average 1885, 1886, 1887	129·7	110·3	109	130	479	119·75
„ 1885, 1886	135	110	114	117	476	11·9
No. Earthquakes in 1887 above (+) or below (−) the average for 1885, 1886	−16	+1	−16	+38	+7	+17

The next table gives the number of earthquakes in 1885, 1886, 1887, arranged according to two seasons, warm and cold:—

—	Warm	Cold	Total	Average
1885	241	241	482	241
1886	249	223	472	236
1887	243	240	483	241·5
Average 1885, 1886, 1887	244·3	234·7	479	239·5
„ 1885, 1886	245	232	477	238·5
No. Earthquakes in 1887 above (+) or below (−) the average for 1885, 1886	−2	+8	+6	+3

The distribution of earthquakes of 1885, 1886, 1887, arranged according to the hours of the day at which they occurred, is as follows:—

—	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	—
A.M.														
12–1	3	8	2	4	5	8	4	3	—	2	6	5	50	
1–2	7	10	3	2	2	7	6	1	6	6	2	6	58	
2–3	8	5	7	6	10	5	6	13	11	1	4	6	82	
3–4	5	5	5	5	12	1	5	7	6	4	5	5	65	
4–5	3	7	—	3	12	4	3	3	6	1	1	2	45	
5–6	4	4	8	2	16	2	6	5	3	7	4	1	62	
6–7	4	5	5	3	6	2	5	3	10	4	2	8	57	697
7–8	4	2	4	6	7	5	3	3	1	6	6	4	51	
8–9	5	5	5	6	8	5	6	4	10	1	3	5	63	
9–10	5	6	6	5	6	10	2	4	7	6	2	3	62	
10–11	10	1	3	7	1	2	2	2	3	2	2	6	41	
11–12	4	5	4	5	8	7	5	2	4	3	4	10	61	
P.M.														
12–1	2	3	2	2	5	3	4	3	7	3	8	6	48	
1–2	2	10	5	6	13	7	4	7	5	6	5	5	75	
2–3	7	2	9	7	11	5	7	4	4	3	7	5	71	
3–4	2	7	1	7	6	1	7	6	7	2	6	3	55	
4–5	3	3	6	2	8	4	2	5	8	1	2	2	46	
5–6	4	9	5	2	4	7	4	—	4	2	1	1	43	
6–7	4	4	6	5	4	5	3	5	8	6	5	6	61	740
7–8	6	7	3	4	2	4	5	4	2	5	3	5	50	
8–9	1	6	5	5	7	3	6	5	5	6	11	11	71	
9–10	2	6	6	2	5	5	8	6	9	5	5	10	69	
10–11	10	11	12	5	6	6	1	6	—	6	5	13	81	
11–12	6	10	4	3	5	6	2	10	3	6	5	10	70	
Monthly totals	111	141	116	104	169	114	106	111	129	94	104	138	1,437	

Severe Earthquakes.

The most severe earthquakes which occurred in 1887 were as follows: July 22 in Echigo; January 15 near Tokio and Yokohama; September 5 in Slumosa; and February 2 in Owari.

The earthquake of January 15, which destroyed a number of houses and opened fissures in the ground, was briefly described in the Report for 1887. The diagram of the motion of this earthquake, together with diagrams of other large disturbances taken at the Imperial Meteorological Observatory in Tokio, are forwarded for inspection.

The earthquake of July 22 was at least as severe as that of January 15, cracking walls and opening many fissures in the ground.

Earthquakes in connection with Magnetic and Electric Phenomena.

1. *Magnetic Phenomena.*

Amongst seismological records we find many accounts where magnets and magnetometers have been affected at or about the time of earthquakes. On November 14, 1799, after the earthquake of Cumana, Humboldt observed a diminution in dip of 48 minutes, and also a change in declination. In 1822 Arago and Biot simultaneously observed movements in magnetometers at Paris at the time of slight shocks in Switzerland and South France. Professor M. S. di Rossi gives several interesting examples where magnets have dropped armatures or iron filings, or there have been sudden changes in magnetic elements at the time of earthquakes. Amongst the observers of these phenomena we find Sarti, Count Malvasia, Palmieri, Secchi, Bertelli, Mascart, Lamont, and others. In Tokio I have often observed disturbances due to mechanical shaking, and one of the first seismoscopes I constructed about fourteen years ago consisted of a small magnetic needle held in a position of unstable equilibrium by the attraction of a piece of iron. On being shaken the needle flew to the iron, where it remained as evidence of a disturbance in every probability mechanical. The observations, however, of the greatest interest are those where the instruments which have been disturbed have been situated well outside any area of perceptible shaking, as, for instance, when magnetographs at Perpignan, Paris, Lyons, Kew, and other observatories were *simultaneously* disturbed at the time of the Riviera Earthquake on February 26, 1887 (*see* 'Nature,' March 3, 1887).

The magnetic disturbance following the eruption of Krakatoa in 1883 progressed westwards and northwards at rates of from 761 to 939 miles per hour, which is apparently a rate very quick even for a dust cloud to travel.

At the Magnetical Observatory in Tokio, where magnetic elements have been recorded photographically for the last few years there do not appear to have been any disturbances at or about the time of earthquakes excepting those which may be accounted for as being due to mechanically produced movements.

The irregularities which exist are most noticeable in the lines indicating changes in declination. They are occasionally visible in the record for horizontal force, but hardly ever in the record for dip.

All the records respecting magnetic disturbances at or about the time of earthquakes which I have been able to collect are being published in vol. xv. of the 'Trans. Seis. Soc. of Japan.'

2. *Electric Phenomena.*

At or about the time of earthquakes, electrical phenomena appear to be more frequent and more pronounced than magnetic phenomena, and the records of such phenomena are found in the description of many large earthquakes. The earthquakes in Catania 1693, at Lisbon 1755, in New England 1727, at Manchester 1777, in Ohio 1812, were all accompanied by electrical phenomena. Humboldt observed that during the earthquake of Cumana the electroscope quickly showed the presence of electricity in the atmosphere.

Telegraphic land lines and submarine cables have often been disturbed by earth-currents at the time of earthquakes. In my second report to this Association, in 1881, I gave an account of earth-currents produced by the shaking of the ground at the time of an explosion of dynamite, and suggested that their origin might be due to the shaking, creating differences in contact between the earth and an earth plate resulting in varying degrees of chemical action.

In Italy Professor Demenico Ragona observed that at the time of an earthquake there was a current passing through a galvanometer to a lightning rod-like conductor in the atmosphere. This observation led me to examine the photographic records of atmospheric electricity taken at the Meteorological Observatory in Tokio. In the instrument which is there used, which is Mascart's, the needle of the electrometer, which has a bifilar suspension, is kept at the potential of the atmosphere by connection with a water dropper, while the quadrants of the electrometer are kept at a constant potential by connection with 50 water Daniells. Through the kindness of the director of the observatory I was enabled to examine records extending over a period of twelve months. These records have been compared not only with the records of earthquakes observed in Tokio, of which there were 99, but also with the records of earthquakes felt in other parts of the empire, of which there were between four and five hundred. The results of these comparisons are as follows:

1. In electrical disturbances which apparently accompany certain earthquakes the air almost invariably becomes electro-negative. The change in potential is sudden, sometimes rising as much as 30 volts. It often takes several hours before the electrometer needle returns to its original position.
2. At the time of earthquakes which have not reached Tokio, electrical disturbances have not been recorded.
3. When Tokio has been at the S.W. extremity of a disturbance shaking an elliptically formed area, the centre of which disturbance may have been 15 or 20 miles N.E. from Tokio, there have been three cases of electrical disturbance, and twelve cases without such disturbances.
4. When the centre of a disturbance has been 50 or 60 miles N.W. of Tokio, there have been two cases of electrical disturbance, and eleven cases without such disturbances.
5. When an earthquake has shaken a narrow band extending from Tokio 30 miles northwards, there have been three cases of electrical disturbance, and no case of no disturbance.
6. When the centre of a disturbance has been 20 to 30 miles E. of Tokio, there has been one case of electrical disturbance, and six cases with no disturbances.
7. When the centre of a disturbance has been from 20 to 100 miles west of Tokio, there have been three instances of electrical disturbance, and three instances when there was no disturbance.
8. If there is a feeble disturbance only felt in Tokio, such disturbances have been 13 times accompanied by electrical disturbances, and 31 times without.
9. If there is a strong disturbance with Tokio near the centre, and shaking an area 60 or more miles in diameter, there have been ten cases of strong electrical disturbance, and only one case where there was no disturbance. Those earthquakes which are the most pronounced in relation to electrical phenomena have not always been accompanied by vertical motion, and they have occurred at different hours.

Comparison of Tokio and Yokohama Earthquakes.

In Yokohama, which is situated about 18 miles S.S.W. from Tokio, it has always been supposed that earthquakes are more frequent and more severe than in Tokio. The only lists of Yokohama earthquakes which I have been able to obtain extend from January 22, 1878, to December 31, 1881, and from March 8, 1885, to December 31, 1889.

These lists have been compiled without the assistance of instruments, and therefore are not so complete as they might have been had the records been founded on indications given by seismographs. The latter list was made by my friend Mr. J. E. Pereira, of Yokohama. Altogether I find for Yokohama notes relating to 285 shocks, and of these 189 were felt in Tokio, or, in other words, 33 per cent. of the Yokohama disturbances do not reach Tokio. Similarly there may be disturbances peculiar to Tokio which do not reach Yokohama.

Velocity of Earthquake Propagation.

In the seventh report to this Association (1885), as the result of a long series of experiments upon disturbances produced by the explosion of dynamite, and by other means, it was stated that velocity of transit decreases as a disturbance radiates, that it increases with the intensity of the initial disturbances, and that in soft ground the author had recorded velocities of from 200 to 630 feet per second, &c. In the same report there is a brief account of the simultaneous observation of earthquakes at several stations in electrical connection. As one pendulum sent time to all these stations, which were 800 or 900 feet apart, on the assumption that at a given station, which we will call A, a particular wave, which we will call *a*, could be again recognised at stations B, C, &c., we had here the best possible means of determining velocity.

As a matter of fact, out of 50 sets of diagrams representing 50 different earthquakes, it was only in five instances that the same wave could be identified at several different stations. The result of these identifications led to the calculations of velocities of 5,860, 4,270, 5,984, 2,850, and 1,644 feet per second.

These determinations, however, cannot be accepted without reserve, because I find that waves may spread out as they pass from station to station, their period may alter, a given wave at one station may split up into two waves by the time it reaches the next station, &c.

Thus on December 16, 1884, I found at station A two waves *a* and *b* separated by an interval of 1·139 seconds, whilst at station B what appear to be the same two waves are 1·277 seconds apart. Hence a velocity calculated from the transit of *a* would be different from the velocity of the same earthquake calculated from *b*. This sort of observation is not uncommon: thus on March 20, 1885, I found at A a wave *a* 1·99 seconds, and a wave *b* 4·11 seconds, from the commencement of the time ticks. At J these same waves are respectively 3·03 and 5·26 seconds from the first time tick. From this we must conclude that in travelling from A to J the wave *a* took 1·04 seconds, whilst the wave *b* took 1·15 seconds.

These observations led to the conclusion that satisfactory results could only be expected by timing the arrival of disturbances at points on an area of considerable extent, and with this end in view, at the request of the Seismological Society, I entered into communication with the telegraph department of this country to obtain their assistance in observing the velocity of earthquake transit.

Such assistance they have given for two years, and Mr. W. B. Mason of Tokio is now publishing a list of the observations which have been made. The stations selected are from 20 to 200 miles apart, and the clocks from which the observations are made by personal observation are corrected every day by a time signal sent from Tokio. Although the hearty thanks of the Society are due to the Telegraph Bureau for the manner in which they have rendered assistance, I regret to report that although the observations have thrown some light on the distribution of seismic energy in North Japan, records which are of value in determining the velocity of earthquake transmission have not yet been obtained.

One or two of the observations, which have extended over a period of two years, suggest that at least sometimes a given earthquake may be felt simultaneously over an area of considerable extent. This was the case with the disturbance of August 2, 1889, which was noted at several places about 100 miles apart at exactly the same time.

At present we have reliable observations on the propagation of earth-waves varying between 200 and 6,000 meters per second, whilst at other times it appears as if a large area received an impulse in all its parts at the same moment.

Sixth Report of the Committee, consisting of Professor W. GRYLLS ADAMS (*Chairman and Secretary*), Sir WILLIAM THOMSON, Sir J. H. LEFROY, Professors G. H. DARWIN, G. CHRYSTAL, *and* S. J. PERRY, Mr. C. H. CARPMAEL, Professor SCHUSTER, Professor RÜCKER, Commander CREAK, the ASTRONOMER ROYAL, Mr. WILLIAM ELLIS, Mr. W. LANT CARPENTER, *and* Mr. G. M. WHIPPLE, *appointed for the purpose of considering the best means of Comparing and Reducing Magnetic Observations.*

AN attempt has been made during the year to organise and bring into form the recommendation of this Committee, made in their report of last year, that it would be desirable to publish annually the curves of the three magnetic elements for different Magnetic Observatories for certain selected days.

This matter has been under the consideration of the Kew Committee of the Royal Society, and a Sub-Committee of that body has been appointed to take charge of it, the Sub-Committee consisting of Professor W. Grylls Adams, Professor Rücker, Commander Creak, with Mr. Whipple as their Secretary (all of whom are members of this Committee).

It seemed of some importance to decide how many days in each month would be required in order to give accurately the mean diurnal range without requiring the elaborate measurements and methods in use at Greenwich, which would be impracticable in observatories where only a small staff is employed.

With this object it was proposed by Professor Rücker to employ the method proposed by Dr. Wild[1] to reduce the mean diurnal range of declination at Kew for two or three years previous to 1888, taking only five quiet days in each month. The years selected were 1883, 1886, and 1887, the first being chosen as being a year of maximum sun-spots. The calculations were undertaken by Messrs. Robson and Smith (two of Professor Rücker's advanced students at the Normal School of Science), and their results, brought before the Physical Society,[2] show a remarkably close agreement with the corresponding Greenwich results. The greatest discrepancy between any curve in which these differences are plotted

[1] See *Brit. Assoc. Report*, 1885, p. 78.
[2] *Phil. Mag.*, August 1890, p. 140.

down and the mean curve deduced from all the six years which have been investigated is 0′·4. They conclude that 'it would seem possible, knowing one set of values for any particular year—Greenwich or Kew—to determine the other set, correct to within four-tenths of a minute.' This close agreement strongly supports the views of Dr. Wild, and at the same time makes it possible to deal practically with the observations from many different observatories, and to obtain trustworthy results. These results completely confirmed those of Mr. Whipple, who made a comparison of the methods of Wild and Sabine with that in use at Greenwich for the years 1870–72 (see 'British Association Report' 1886, p. 71), as to the nature of the difference between the diurnal variations at Greenwich and Kew as given by the two methods of reduction. The Astronomer Royal has not only undertaken to select the five quiet days of each month and communicate them to the other observatories as soon as possible after the end of each year, but he has also offered to reduce the Greenwich results by Wild's method as well as by that now in use at Greenwich.

The following list of quiet days has been prepared by the Astronomer Royal from the Greenwich records as suitable for discussion in the year 1889:—

January	3, 6, 15, 24, 27.
February	4, 10, 13, 22, 25.
March	3, 10, 19, 21, 24.
April	5, 11, 16, 17, 19.
May	3, 9, 16, 21, 25.
June	5, 8, 12, 24, 27.
July	4, 9, 15, 22, 25.
August	3, 5, 14, 24, 30.
September	4, 7, 15, 20, 29.
October	4, 11, 16, 23, 27.
November	5, 13, 15, 19, 21.
December	4, 10, 18, 19, 25.

The Committee of the Falmouth Observatory and the Rev. W. Sidgreaves of Stonyhurst have expressed their willingness to accept the same series of days for discussion, and M. Mascart of Paris and M. Moureaux of Parc St. Maur will also select and use for discussion the same typical days. Dr. Wild has published in the Bulletin of the Imperial Academy of Science of St. Petersburg a paper on the normal variation and the disturbances of the declination, in which he recommends the adoption of his method, and shows that during the last fifteen years there have been on an average seventy-two days per annum suitable for discussion as undisturbed days. Dr. F. Schmidt of Gotha has discussed the daily variation of terrestrial magnetic force for Vienna for every month of the years 1879–88, and has represented them as numbers of a periodic series.

In consequence of the expression of their opinion in their reports of last year, 'that the establishment of a Magnetic Observatory at the Cape of Good Hope would materially contribute to our knowledge of terrestrial magnetism,' this Committee has received a letter from Mr. David Gill, the Director of the Royal Observatory, Cape of Good Hope, offering every facility in his power to forward the objects of the Committee. Mr. Gill reports that there is ample room for the establishment of the necessary buildings, and that he is prepared with hearty good-will to undertake the direction, administration, and control of the work, but that an additional observer will be required to carry out the magnetic work under his direction.

The Committee greatly regret that they have to record the deaths of Sir J. H. Lefroy and of Professor S. J. Perry, who have done very valuable work for this Committee, and who have greatly advanced our knowledge of the subject of terrestrial magnetism.

Report of the Committee, consisting of Professor CRUM BROWN (*Secretary*), Mr. MILNE-HOME, Dr. JOHN MURRAY, Lord MCLAREN, Dr. BUCHAN, *and the* Hon. RALPH ABERCROMBY (*Chairman*), *appointed for the purpose of co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.*

DURING the past year the hourly observations, by night as well as by day, at the Ben Nevis Observatory, have been made by Mr. Omond and the assistants without interruption; and the five daily observations at the sea-level station at Fort William have been also made by Mr. Livingstone with the greatest regularity.

Again the state of the health of the observers, owing to the circumstance that active exercise in the open air is practically precluded during most of the year, rendered it necessary to give them relief during the winter and spring months. This relief the directors of the observatory were the better able to give through the courtesy of the following gentlemen, who gave their services as observers for periods varying from four to six weeks:—Mr. Alexander Drysdale, M.A., B.Sc., Mr. Charles E. Gray, Mr. James McDonald, M.A., Mr. R. C. Mossman, and Mr. Robert Turnbull, B.Sc. During the time Messrs. Omond and Rankin were in Edinburgh they gave much valuable help in the discussion of the Ben Nevis observations, and otherwise assisted in the work of the office of the Scottish Meteorological Society.

Mr. Omond has completed an important investigation of the temperature of Ben Nevis. From the six years' observations he has calculated the mean temperature of each day of the year for the observatory at the top and for the low-level station at the foot of the mountain, and made a comparison of the two series of temperatures. The paper is in type, and will appear in the forthcoming 'Journal of the Scottish Meteorological Society.' He has also re-examined the estimations of wind force and their equivalents in miles per hour from all the observations now available for the purpose, and the results are ready for publication in the same journal.

Mr. Rankin has carried on, as the time at his disposal from his regular duties at the observatory permits, the work of photographing clouds and other meteorological phenomena.

In the autumn of last year a grant of 50*l.* was obtained from the Government Research Fund for carrying on an investigation into the numbers of dust particles in the atmosphere, by means of two sets of apparatus invented by Mr. Aitken, one being permanently fixed in the tower of the observatory, the other being a portable form of the instrument. Mr. Aitken superintended the construction of both instruments, and the placing of them with the necessary precautions at the top of the mountain. Reference will be made further on to the remarkable results obtained by the observations Mr. Rankin has already made.

Messrs. Omond and Rankin are still engaged with the laborious inquiry into the directions of the winds observed at the top, with the winds observed at low-level stations at the same hours, and their relations to the weather of North-Western Europe. The comparative frequency with which the winds at the observatory blow, not with, but against, the isobarics of low-level stations, and indicate a force widely different from the barometric gradients of the weather maps of the Meteorological Office, are striking elements in the meteorology of Ben Nevis.

The 'Report for the Transactions of the Royal Society of Edinburgh' on the Ben Nevis and Fort William observations is in type, and will appear shortly. An early copy of the volume is submitted with this report to the British Association.

For the year 1889 the following were the monthly mean pressures and temperatures, hours of sunshine, amounts of rainfall, and number of fair days at the observatory; the mean pressures at Fort William being reduced to 32° and sea-level, those at the Observatory to 32° only:—

TABLE I.

—	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean Pressure in Inches.													
Ben Nevis Observatory	25·390	25·202	25·280	25·153	25·301	25·545	25·406	25·267	25·465	25·134	25·463	25·339	25·329
Fort William	30·014	29·857	29·909	29·745	29·785	30·050	29·903	29·746	29·994	29·668	30·066	29·953	29·891
Difference .	4·624	4·655	4·629	4·592	4·484	4·505	4·497	4·479	4·529	4·534	4·603	4·614	4·562
Mean Temperatures.													
Ben Nevis Observatory	27°·5	21°·4	24°·4	25°·9	38°·1	43°·1	40°·8	38°·7	37°·7	30°·3	30°·3	26°·8	32°·1
Fort William	41·0	37·4	41·2	44·3	55·9	57·8	57·6	55·9	53·4	46·0	44·6	41·0	48·0
Difference	13·5	16·0	16·8	18·4	17·8	14·7	16·8	17·2	15·7	15·7	14·3	14·3	15·9
Extremes of Temperature.													
Max. Temp.	29°·2	36°·3	40°·7	43°·7	50°·7	60°·0	61°·8	48°·1	54°·4	38°·3	44°·1	38°·0	61°·8
Min. Temp.	16·9	6·4	11·2	15·2	27·7	28·0	29·1	30·1	21·1	21·8	12·5	13·2	6·4
Difference .	22·3	29·9	29·5	28·5	23·0	32·0	32·7	18·0	33·3	16·5	31·6	24·8	55·4
Rainfall in Inches.													
Ben Nevis Observatory	17·69	14·86	12·11	3·89	4·34	1·94	4·09	18·32	7·28	6·62	11·48	18·04	120·66
Days of no Rain	6	2	6	9	10	15	9	2	10	8	3	5	85
Fort William	10·31	8·77	6·25	3·12	2·73	0·84	1·35	7·58	3·88	4·72	4·91	10·90	65·36
Hours of Sunshine at Ben Nevis Observatory.													
No. of Hours	23	27	27	52	74	213	97	9	46	44	11	11	634
Possible Hours	231	264	363	426	508	529	528	467	381	319	242	210	4,470

At Fort William the mean temperature was 0°·8 under the average, the greatest defect from the means being 1°·8 in February, and the greatest excess 5°·6 in May—indeed, the outstanding feature of the meteorology of the year being the all but unprecedentedly high temperature of May, a temperature, as regards Scotland, only once exceeded since 1764, or during the past 126 years. At the top of the Ben the excess above the mean was greater, amounting to 7°·7, as happens during all unusually high summer temperatures when anticyclones prevail.

The minimum temperature on Ben Nevis was 6°·4, which occurred at 7 A.M. of February 10. This is absolutely the lowest temperature which has been recorded since the opening of the observatory in December

1883. The maximum was 61°·8 on July 4. Thus the extreme range of temperature for the year was 55°·4.

The registrations of the sunshine-recorder showed 634 hours of sunshine as against 970 hours of the previous year, the latter year thus showing a half more hours. The largest number, 213, was recorded in June, and the lowest, 9, in August, being the lowest that has occurred hitherto in any summer month. As the highest possible hours for the whole is 4,470, sunshine prevailed on the top of the Ben during only one hour in seven in 1889.

The amount of the rainfall during the year was 120·66 inches, being about ten inches less than the average, the least rainfall being 1·94 inch in June, and the greatest 18·04 inches in December, and 17·69 inches in January. The number of days on which the precipitation was either *nil* or less than 0·01 inch, was 85, or 15 days fewer than the average; the least being 2 in February and August, and the greatest 15 in June. On the other hand, the number of days on which 1 inch of rain or more fell was 37, or nearly one day in 10, being a little less frequent than in previous years. The highest fall for any day was 2·93 inches on August 28; and from March 23 to 25 there fell 5·83 inches. No rain fell from June 16 to 27; on the other hand, from 3 P.M. of December 7 to 1 A.M. of the 11th, there was only one hour without rain.

Atmospheric pressure at Fort William was 29·891 inches, or 0·063 inch above the average pressure. In November it was 0·255 inch above the mean, and in October 0·183 inch below it. June was not only the month of greatest pressure, but it was also the month of highest mean temperature, being about 5 per cent. in excess of its average. This conjunction of high temperature with high pressure during the summer months is a noteworthy feature in the meteorology of the Ben, these occurring during the times when anticyclonic weather prevails over this part of Europe. It will also be observed that during the time the temperature difference between the high and low level stations was only 14°·7, or about two degrees less than the average of June. In June 1887, when the anticyclonic systems were more pronounced than in 1889, the difference fell as low as 12°·9. At these times the air is markedly dry as well as warm, pointing for the explanation to the descending currents of the anticyclones, and not to ascending currents from the superheated lower grounds. It may be remarked here that the observations of the wind on the top of the mountain show conclusively that the outflowing winds from cyclonic to anticyclonic regions set in sooner and at greatly lower levels than had previously been supposed.

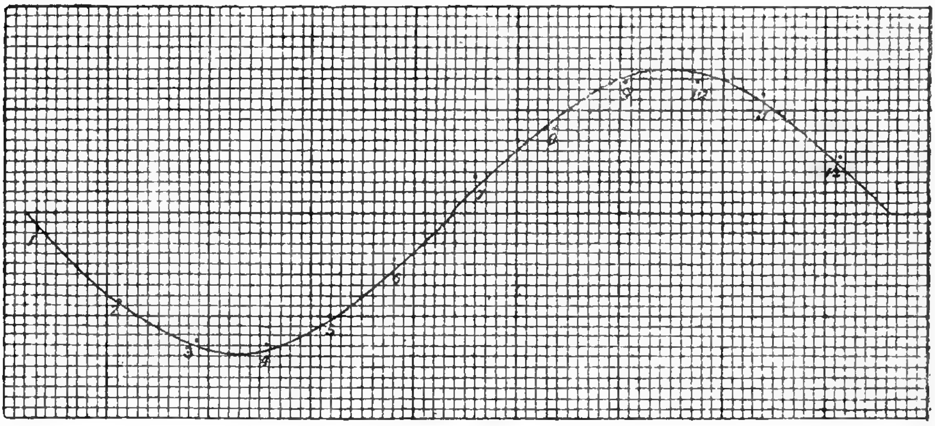
Observations have now been made on Ben Nevis for upwards of six years, or since the observatory was opened in the end of 1883, and, if the observations by Mr. Wragge be added, for nine years during the warmer months from June to October; and during the same time observations have been made near sea-level at Fort William.

As these form a unique double series of observations in meteorology, and as they furnish the observational data necessary in all investigations in atmospheric physics into which height in the atmosphere enters, it is thought to be useful to embody in this Report, in Table II., the more prominent of the results derived from the observations of the two stations. The times from which the data have been deduced are six years from January to May, nine years from June to October, and seven years for November and December. The times are strictly the same for the two stations. The barometric observations at Fort William are reduced to sea-level, those for Ben Nevis only to 32°.

TABLE II.—*Means from* 1881 *to* 1889.

—	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
						Mean Pressures in Inches.							
Ben Nevis Observatory	25·193	25·244	25·246	25·259	25·322	25·460	25·356	25·363	25·384	25·299	25·213	25·201	25·295
Fort William	29·823	29·876	29·873	29·850	29·866	29·970	29·841	29·850	29·887	29·840	29·797	29·804	29·856
Difference .	4·630	4·632	4·627	4·591	4·544	4·510	4·485	4·487	4·503	4·541	4·584	4·603	4·561
						Mean Temperatures.							
Ben Nevis Observatory	25°·1	22°·8	23°·0	26°·3	32°·1	38°·6	40°·3	39°·7	37°·5	31°·8	27°·8	24°·9	30°·8
Fort William	39·0	38·1	39·6	44·8	48·8	55·1	56·7	56·1	52·7	47·2	42·0	39·1	46·7
Difference .	13·9	15·3	16·6	18·5	17·7	16·5	16·4	16·4	15·2	15·4	14·2	14·2	15·9
						Highest Mean Temperatures.							
Ben Nevis Observatory	28°·8	27°·3	24°·6	27°·4	38°·1	45°·6	42°·3	42°·3	40°·0	35°·0	30°·4	28°·2	° —
Fort William	41·5	41·1	42·1	46·3	55·8	58·9	58·5	59·0	55·2	50·1	44·8	43·0	—
Difference .	12·7	13·8	17·5	18·9	17·7	13·3	16·2	16·7	15·2	15·1	14·4	14·8	15·5
						Lowest Mean Temperatures.							
Ben Nevis Observatory	20°·0	20°·8	20°·4	25°·4	26°·8	35°·6	38°·6	37°·1	34°·8	28°·5	26°·2	20°·2	° —
Fort William	35·8	35·0	37·1	43·2	45·7	53·3	54·9	53·2	51·1	42·4	40·2	34·5	—
Difference .	15·8	14·2	16·7	17·8	18·9	17·7	16·3	16·1	16·3	13·9	14·0	14·3	16·0
						Mean Rainfall in Inches.							
Ben Nevis Observatory	14·36	11·35	8·84	5·55	7·16	6·75	9·76	11·34	10·76	12·06	14·09	18·00	130·02
Fort William	9·27	8·09	4·98	4·02	3·81	3·20	5·51	5·46	5·41	6·80	8·37	9.82	74·74
Difference .	5·09	3·26	3·86	1·53	3·35	3·55	4·25	5·88	5·35	5·26	5·72	8·18	55·28
						Greatest Monthly Rainfall.							
Ben Nevis Observatory	17·80	16·94	12·82	9·53	12·87	12·31	15·19	18·32	20·87	20·24	20·60	25·29	—
Fort William	12·73	12·45	6·25	4·98	6·39	6·25	10·88	7·58	11·71	13·77	13·55	13·86	—
Difference .	5·07	4·49	6·57	2·55	6·48	6·06	4·31	10·74	9·16	6·47	7·05	11·43	6·70
						Least Monthly Rainfall.							
Ben Nevis Observatory	7·53	2·84	5·90	3·89	39·7	1·94	4·09	7·56	6·09	6·41	8·99	10·98	—
Fort William	5·63	1·06	3·49	3·12	18·6	0·84	1·35	3·02	1·97	4·04	4·91	7·09	—
Difference .	1·96	0·22	2·41	0·77	2·11	1·10	2·74	4·54	4·12	2·37	4·08	3·89	2·49
						Fair Days at Ben Nevis Observatory.							
Fair Days .	8	7	10	12	10	12	5	8	9	6	7	6	100
Maximum .	12	13	14	15	17	18	13	20	16	11	13	10	172
Minimum .	1	2	3	7	4	7	0	2	2	2	3	3	36
						Sunshine in Hours at Ben Nevis Observatory.							
Sunshine in Hours	33	44	47	76	89	149	80	58	68	33	23	19	719
Maximum .	70	73	74	120	129	250	162	116	121	41	51	28	970
Minimum .	15	18	27	52	31	55	47	9	25	16	8	11	576
Possible Hours	231	264	365	426	508	529	528	467	381	319	242	210	4470

The horizontal distance between the two stations being only about four miles, the monthly variation in the difference of the atmospheric pressures at the two stations is virtually a temperature effect. As the temperature falls to the annual minimum in winter, the air contracts, and a portion of it consequently falls below the level of the barometer at the top, thus reducing the readings there, and increasing the differences between the two barometers. The difference then reaches 4·632 inches, the maximum for the year. On the other hand, as temperature rises, a portion of the atmosphere is raised above the level of the higher barometer, thus increasing the pressure there, and lessening the difference to 4·485 inches in July, the minimum of the year. The difference between the maximum and minimum is thus 0·147 inch. For these months the mean temperatures of the stratum of air between the top and bottom of the mountain are respectively 30°·5 and 48°·5. Hence the vertical displacement of the mass of the atmosphere for a temperature difference of 18°·0 is represented by a barometric difference of 0·147 inch. The sea-level pressures in these months are, however, respectively 29·876 inches in February, and 29·841 inches in July. If, then, we assume the sea-level pressure of July to be the same as that of February, viz. 29·876 inches, the difference between the top and bottom pressures would be not 4·485, but 4·490 inches. From this it follows that the vertical displacement for a temperature difference of 18°·0, and at the same sea-level pressure, is 0·142 inch.



Annual curve of the differences of barometric readings for high and low level stations (Ben Nevis and Fort William).

In order to determine the curve of the table of the barometric differences, it is convenient that these should be reckoned from the mean point, or say 4·560. When so treated, the differences are:—

May	−·016	November	+·024
June	−·050	December	+·043
July	−·075	January	+·070
August	−·073	February	+·072
September	−·057	March	+·067
October	−·019	April	+·031

These quantities being laid down as vertical ordinates, with Time as the horizontal ordinate, it was evident to the eye that the curve was a projection of the curve of sines. The difference between the extreme and mean values in $\frac{1}{1000}$ parts of an inch is 75. Hence, if a be the time expressed in arc, and $\delta\beta$ the differences in the preceding table, we have

$$\tfrac{1}{75}\,\delta\beta=\sin a.$$

The above diagram represents the curve of this equation, and the points numbered from 1 to 12 are the twelve tabular places, beginning with May and ending with April. The curve evidently satisfies the observations.

The relative mean readings of the thermometer are approximately represented by

$$\frac{1}{9}\,T = \sin\alpha;$$

but the deviations from the true curve are greater than in the first case. Comparing the two expressions, the barometric differences are seen to be proportional to the increments of the mean temperature of the two stations. Accordingly, when the places of the table of barometric differences are laid down as co-ordinates to the places of the temperature table, the points are found to lie in approximately straight lines. One would have expected a less simple relation between the quantities in the two tables.

In consideration of the successful arrangements which have been made to minimise the effects of solar and terrestrial radiation at both the high and the low level observatories, and their close proximity to each other, the above result may be regarded as the most important datum hitherto contributed by meteorology for the discussion of inquiries dealing with the relations of height to pressure and temperature in the free atmosphere. The same consideration gives also a peculiar value to the table of corrections, empirically determined from the observations, for the reduction to sea-level of the barometrical observations at the top, calculated for every tenth of an inch of the sea-level pressure, and every two degrees of mean temperature of stratum of air, 4,407 feet thick between the two observatories.

The mean annual differences of temperature of the top and bottom of the mountain, calculated from (1) the mean monthly temperatures, (2) the highest mean monthly temperatures, and (3) the lowest mean monthly temperatures, are respectively 15°·9, 15°·5, and 16°·0. The smaller difference obtained from the highest monthly temperatures was entirely caused by the unusually high temperatures at the top of the mountain during the anticyclonic weather that prevailed in the Junes of 1887 and 1889, in which from the prevailing strong sunshine the whole mountain was in a sense superheated.

During these years the mean annual rainfall at the top is 130·02 inches, and at Fort William 74·74 inches. At the top the maximum monthly mean is 18·00 inches in December, and the minimum 5·55 inches in April; whilst at Fort William there are 9·82 inches in December and 3·20 inches in June. The monthly differences are very striking, being only 1·53 inch in April, but 8·18 inches in December. As holds generally in the north-west of Scotland, the rainfall shows a steady droop to the minimum in June, but on the top of the Ben the minimum is reached in April, and by midsummer has risen considerably above it, due, in all probability, to a more copious precipitation from the ascending currents of the warmer months of the year.

The mean monthly differences for the year between the rainfall at the top and bottom of the mountain, calculated (1) from the mean monthly rainfall, (2) the greatest monthly fall, and (3) the least monthly fall, are respectively 4·61, 6·96, and 2·49 inches. The first of these means is approximately the mean of the other two, giving thus the curious result that in exceptionally wet months the difference between the rain-gauges rises just as much above the normal difference as it falls below the same difference in exceptionally dry months.

At the observatory at the top the annual number of fair days, or days when the rainfall is less than the hundredth of an inch, on the mean of the six years 1884–89, is 100, the monthly mean rising to the maximum of 12 days in April and June, and falling to the minimum of 5 days in July. For any separate month the greatest number of dry days was 20 in August 1885, whereas in July 1886 no dry day occurred at all.

The sunshine record extends from March 1884 to the end of 1889. The results show an annual mean of 719 hours' sunshine against a possible 4,470 hours. Thus, during these six years, the hours of sunshine shown by the Campbell-Stokes sunshine-recorder have been nearly one-sixth of the number possible. The mean monthly maximum is 149 in June, and minimum 19 in December. In December the number has been persistently low, even the highest being only 28 hours in 1887. On the other hand, in June the number has exceeded 200 in each of the last three years, rising to 250 hours in 1888; whereas the highest number for any of the other eleven months was only 162 hours in July 1885. As will be seen from Table II. the differences between the maximum and the minimum numbers of the months are very great. For each of the five years of complete observations the number of hours were 680, 576, 898, 970, and 634—thus also showing enormous differences among the separate years.

As regards diurnal phenomena, the hourly variation for each month has been calculated for temperature, pressure, humidity, cloud, rainfall, wind-velocity, and sunshine. Results of great value have been arrived at, for which, however, we must, in this brief report, refer to the volume herewith submitted to the Association.

In addition to the usual routine work of a first-order meteorological observatory, other observations have been carried on, mostly of a novel character, for which the observatory affords exceptional facilities.

The rapid formation of snow crystals, in certain states of weather, from fog, on the observatory and every object exposed to these drifting fogs, has been carefully observed and investigated by Mr. Omond. With these rapid accretions, the cups of Robinson's anemometer are no longer hemispheres, but irregular hollow bodies, bristling all over with pointed crystals, and the arms increased to many times their original thickness, and thus the whole instrument soon becomes a mass of immovable snow, and further observation is rendered impossible. The thermometer box, with its louvre boards, similarly becomes serrated with rows of teeth, which quickly coalesce into a solid, and the instruments are no longer in contact with the free atmosphere. In these circumstances a fresh box is put out. It is thus that at observatories such as Ben Nevis, owing to these accretions of ice on the thermometers, the continuous or hourly registrations of the temperature of the air must be for ever impossible. In truth, such observations must always be eye observations, where the observer personally sees that, previously to the recording of each observation, the thermometer is in contact with the free atmosphere, and is not sheltered from it by a coating of ice. The importance of thermometric observations is emphasised by the circumstance that without them the barometric observations are of comparatively small value. Ben Nevis is the only observatory that has hitherto coped, and that successfully, with this all-important department of the work of a high-level observatory;

and one cannot sufficiently admire the heroic endurance with which the observers have made the hourly observations by night and by day, during summer and during winter.

The direction of the winds indicates a well-marked diurnal variation. From 3 to 8 A.M. northerly winds of about $2\frac{1}{2}$ miles an hour, and from 11 A.M. to 2 P.M. southerly winds of about 3 miles an hour prevail.

From three years' observations, ending May 1887, it appears that the mean temperatures of the different winds are, S., 32°·6; S.W., 32°·5; W., 31°·4; N.W. and S.E., 30°·2; E., 27°·8; N., 27°·6, and N.E., 26°·5. The warmest point in the windrose oscillates from S.W. in winter, passing through S. to S.E. in summer. The annual temperature range of easterly winds is 20°·7, but westerly only 15°·6.

Observations of the rainband were begun in June 1885. The observed higher values are accompanied, or soon followed, by a heavy rainfall, which tends to become less heavy in the next twelve hours. The lower values, on the other hand, though they may be neither accompanied nor followed in the next three hours by any rain, are followed by a considerable rainfall before the twelve hours are run. With the same rainband value precipitation is less with a higher and greater with a lower temperature. If the temperature immediately falls the rainfall is greatly increased, but if it rises it is less than it would have been if the temperature remained constant. The highest values, with accompanying very heavy rains, are part and parcel of the cyclones which come to us from the Atlantic laden with moisture and warmth. The rainband is not affected during heavy rains, the result of moisture-laden air ascending from lower levels; and during the states of the air attending the rapid deposition of snow crystals no rain falls, though at the time the rainband values are high.

As respects forecasting the weather, the most important observations are those showing a decreasing rainband from hour to hour. A comparison of these observations with the daily weather-charts and subsequent observations show that the decreasing rainband indicates that the moist air aloft is slipping away or sinking below the level of the summit, and that the air taking its place is comparatively dry. Now this state of things appears to be the earliest indication we at present have that an anticyclone is beginning to form and settle over this part of Europe.

St. Elmo's Fire is not an infrequent occurrence on Ben Nevis. The observed cases have occurred during the night and during the winter months from September to February. A careful discussion of the cases shows that the weather which precedes, accompanies, and follows has quite peculiar characteristics not only on Ben Nevis but also over the West of Europe generally—indeed, so well marked is the type of weather and so notorious is it for its stormy character, that it is familiarly known at the observatory as 'St. Elmo's weather.' It is further observed that in almost every case another cyclone, with its spell of bad weather, follows the particular cyclone in which St. Elmo's Fire is observed.

The winter thunderstorms occur under the identical weather conditions under which St. Elmo's Fire occurs. They invariably occur on the south-east side of the cyclone's centre, with the easterly passage of which they appear to be intimately connected. The thunderstorms and cases of sheet-lightning of Ben Nevis are essentially autumn and winter occurrences, 70 per cent. of the whole having occurred from September to February. They are rare in summer, only eight having occurred from May to August, having an annual period just the reverse of what obtains in the eastern districts of Scotland. During the summer they are twice as frequent at Fort William as at the observatory, thus suggesting that a considerable number must be below the summit, or in the aerial stratum between the high and low level observatories. All the summer thunderstorms have occurred when the sun was above the horizon; but of the thirty-seven cases in autumn and winter thirty-two took place when the sun was below the horizon. These results are of great value in their relation to the distribution of thunderstorms and other electrical displays over the land and the water surfaces of the globe.

An elaborate series of hygrometric observations have been made at the observatory with the view of inquiring how far Glaisher's factors can be safely used. For the conduct of such an inquiry, the low-temperature humidities and remarkably dry states of the air which form so prominent a feature in the climatology of Ben Nevis, the observatory offers unique facilities. The observations were made with the ordinary dry and wet bulb hygrometer and Professor Chrystal's direct hygrometer, with the result that a specially constructed set of tables is required for the extremely low humidities of Ben Nevis, these being considerably lower than Mr. Glaisher had had an opportunity of observing.

Professor C. Michie Smith has shown that on the edge of a dissolving mist the potential is lower than the normal, but higher on the edge of a condensing mist. Now, almost always when the top of Ben Nevis becomes clear for a short time, a strong current comes up the telegraph cable, while as soon as the summit is again enveloped the current is reversed. The connection between the moisture of the atmosphere and the earth currents is still further shown by the rainfall. During a fall of rain or snow the current nearly always passes down the cable; and in the case of a sudden shower the current has sometimes driven the mirror of the galvanometer violently off the scale. A cessation of the rain or snow generally has an exactly opposite effect. If it be assumed that the summit of Ben Nevis takes the potential of the masses of vapour covering it, and if we consider the earth-plate at the base as the earth, or zero of potential, it is obvious that these results confirm the theory advanced by Professor Michie Smith, a conclusive proof of which would be of the greatest importance in investigations connected with thunderstorms.

Observations on the numbers of dust particles with the apparatus invented by Mr. Aitken have recently been undertaken at the observatory. Already noteworthy results have been obtained. On March 31, at 4.30 P.M., the summit was clear, and the number of particles per cubic centimètre was 2,785; but shortly thereafter a thickness was observed approaching from south-west, which by 6 P.M. reached the observatory, and the number of particles rose to 12,862, being the maximum yet observed. On June 15 many observations were made during the day, when the number of particles fell from 937 at midnight to 50 at 10.30 and 11.42 A.M. Still more remarkable were the observations of July 20–21. Till 10 P.M. of the 20th the wind at the top of the mountain was about the direction as at sea-level, viz., south-west to west-south-west; but at that hour it went suddenly round to north, increasing at the same time to 40 miles an hour, and temperature rose from 41°·0 to 47°·0, and soon after to 49°·2. At the low-level observatory temperature remained exceptionally constant at 55°·0 from 9 P.M. till 4 A.M. of the 21st. At the high-level observatory ten observations made between 2 and 3 A.M. gave the extraordinary low mean of only two dust particles to the cubic centimètre. During this time the high-saturated, high-temperatured north wind was blowing out of the cyclone which lay to northward, whilst the sea-level winds were south-west, or were blowing in upon the same cyclone. The observations already point to a daily maximum during the time of the afternoon minimum barometer, and a minimum number during the morning minimum barometer, or during the times of the great diurnal ascending and descending currents of the atmosphere. It is evident that in these observations we have indications of intimate relations subsisting between the numbers of dust particles and the cyclones and anticyclones over North-Western Europe at the time. It is also made clear that the dust particles vary enormously during the presence of mist or fog without being accompanied with any difference in the apparent density of the fog.

It is unnecessary to dwell at length on the prime importance of these observations and investigations conducted at the Ben Nevis observatories in their relations to cyclones and anticyclones on which our weather depends, and the bearing of the whole matter on the framing of weather forecasts. To this subject it is arranged that Dr. Buchan's time will be wholly given during next year. In carrying out this intricate and laborious investigation, the Meteorological Council send Mr. Omond three copies of their 'Daily and Weekly Weather Maps,' on which are to be entered certain of the meteorological data from the high and low level observatories, and comparisons of those data, together with occasional remarks that may from time to time be made as bearing more or less closely on forecasting weather. One of these sets will be sent to the Scottish Meteorological Society, and another to the Meteorological Council, while the third will be retained by Mr. Omond at Fort William.

The low-level observatory has been equipped by the Meteorological Council with a complete set of self-recording instruments, and the regular observing work began on July 14. The directors are thus now in the best possible position for extending the scientific and practical inquiries they have taken in hand by the unique facilities offered by these two well-equipped observatories.

Sixth Report of the Committee, consisting of Professors A. Johnson (*Secretary*), J. G. MacGregor, J. B. Cherriman, *and* H. T. Bovey *and* Mr. C. Carpmael, *appointed for the purpose of promoting Tidal Observations in Canada.*

Your Committee is happy to be able to report that the Canadian Government has at length undertaken to establish stations for systematic tidal observations, and that the calculations for the tide-tables will be made according to the method recommended by the Association. It is understood that the construction of the tables will be entrusted to Mr. Roberts, of the Nautical Almanac Office. That the efforts of the Committee were not successful earlier is possibly due to the fact that there have been three Ministers of Marine in succession since the Committee was appointed, and that the Committee had, in each case, to begin *de novo* to present the facts to the Minister in office in order to convince him personally of the need of the observations for the purposes of practical navigation. The character of the British Association as scientific was, to a certain extent, a positive obstacle to the efforts of the Committee, instead of an aid. Notwithstanding the courtesy with which deputations from your Committee were invariably received by the Minister or the Cabinet on the occasions of an interview, it was obvious that there was always lurking in the background a suspicion that the Committee might, not unnaturally, take an exaggerated view of the practical value of the observations in their appreciation of the scientific interest of their results, and this notwithstanding the fact that there is not at the present moment a single official tide-table, giving the rise and fall of tide, for any of the ports of the Dominion, and that ocean steamers run aground in places where they ought not if sufficient information were supplied them. Nor is information as to the tidal currents obtainable, though the want of it is the cause of numerous wrecks and great consequent loss of life and property, as shown by the annual wreck lists for years past.

The Committee has been earnest in pressing both of these needs of navigation on the attention of the Government, and has been most effectively supported in its efforts by a committee of the Royal Society of Canada, of which Dr. Sandford Fleming, C.M.G., President of the Society, was chairman. Sir William Dawson, C.M.G., former President of the British Association, has on every occasion this year, as heretofore, given his valuable assistance and taken part in the efforts of your Committee.

A petition to Parliament from nearly 400 masters and officers of ships asking for survey of the tidal currents (involving, of course, observations at fixed stations on the rise and fall) was circulated during the last session, and a petition to the same effect was presented also by the 'Shipping Interest' of Montreal. This latter body obtained an interview with the Cabinet to discuss the question, at which were present, besides their own deputation headed by their chairman (Mr. Andrew Allan, of the Allan Line), the Chairman of the Board of Trade of Montreal (Mr. Cleghorn), and members of both committees, including those members above named.

Subsequent to the interview the Minister of Marine (the Hon. C. H. Tupper) continued the inquiries which he had been making of the Committee. These were so thorough and searching that the Committee has the satisfaction of feeling that any extra labour thereby caused them is well repaid by the fulness of the proofs of the great practical value of the observations of both kinds presented to the Minister; proofs to which the Minister himself added by his independent inquiries from others, including the Hydrographer of the Admiralty and the Superintendent of the Coast and Geodetic Survey of the United States.

The only matter of regret is that the grant for the present year is not sufficient to establish at the moment more than three or four stations. An anticipatory grant for next year to establish others was, it is understood, not presented to Parliament in consequence of the absence of the Minister at Washington in connection with the negotiations going on with the United States; but it will, no doubt, be made next session. Observations of such importance to the commercial interests of Canada, having been once begun by the Government, must necessarily be continued to be of any service.

The Committee considers that it has thus brought to a successful conclusion the work for which it was appointed, and therefore begs to be discharged.

Report on the Present State of our Knowledge in Electrolysis and Electro-chemistry. *By* W. N. SHAW, *M.A.*

THE scientific aim of the theory of electrolysis has been stated by F. Kohlrausch to consist in the reference of electro-chemical phenomena to mechanical processes and mechanical or electro-mechanical laws. It is the purpose of this report to enable its readers to form for themselves, by a comprehensive survey of work done in furtherance of that aim, an opinion as to the real steps that have been taken towards its achievement, the causes which have stood in the way of its more complete fulfilment, and, if possible, to get some idea as to probable directions of future progress. It is hardly necessary to say that the aim in question has not yet been fully attained. Multitudes of experiments have been described in scientific publications; some generalisations and laws have been established, and various forms of electro-mechanical theory of electrolysis are at present under discussion; but they are not yet fully developed, nor, indeed, have rival theories been stated in such clear forms as to lead to the suggestion of crucial experiments.

A very concise yet complete summary of the facts and theories relating to electrolysis and electro-chemistry up to the end of 1882 has been compiled by Professor G. Wiedemann, and is the more valuable as its author is himself so successful a worker in that field. The summary is contained in Wiedemann's 'Electricität,' mainly in the second volume. The whole of the account of electrolysis and allied subjects occupies few, if any, less than a thousand of Wiedemann's ample pages. No student of electrolysis can fail to owe a debt of gratitude to the author of this large collection of facts and theories. Since its publication, however, the attention of many scientific men has been directed towards electro-chemistry. Von Helmholtz in his Faraday Lecture (April 5, 1881) [1] pointed out the importance of the subject; and the Electrolysis Committee of the British Association, appointed jointly by Sections A and B, after the discussion of the subject at Aberdeen in 1885 opened by Dr. O. J. Lodge, has, under his able direction, maintained the interest in it. A great deal of work has been done, especially towards comparing the numerical values of electrolytic conductivity of a compound with those of its other physical properties; moreover, Svante Arrhenius, in a memoir presented to the Academy of Sciences of Sweden in 1883, has based the numerical calculation of a number of chemical actions upon the numbers expressing the electrolytic conductivity of the interacting substances. The application by Von Helmholtz of the second law of thermodynamics to chemical and electro-chemical processes in 1877 and 1882 has led to extensive researches in the thermodynamics of electrolysis. The years since the close of 1882 have accordingly witnessed a very remarkable activity in the development of electrolytic subjects. Apart from memoirs on special sections in current scientific literature, a general survey of the field by Lodge in 1885, forming the opening address in the discussion at Aberdeen, is printed in the British Association report of that year, in which, perhaps, the foreshortening of the subject, natural to the point of view of a leader

[1] *Jour. Chem. Soc.* 39, p. 277.

of discussion, is somewhat conspicuous. There is, moreover, a short but very interesting sketch of the subject in 1887 by one of the founders of its new development, published in the 'Electrotechnische Zeitschrift,' June 1887, under the title of 'Die gegenwärtigen Anschauungen über die Electrolyse von Lösungen,' by F. Kohlrausch, and a brief statement of the problems in the subject was given by G. Wiedemann at the meeting of the British Association at Manchester in 1887 ('Report,' p. 347).

The order of arrangement of this report will be :—

(I.) A general statement of the actions, physical and chemical, produced by the passage of electricity through a typical electrolytic cell. This is introduced for the purpose of securing definiteness in the conceptions and language, and to set forth the phenomena which any theory of electrolysis must primarily be able to explain. It will also serve as a guide to the classification of the experimental data available for testing or illustrating electrolytic theories.

(II.) A statement of those generalisations and laws which are accepted by all workers in the subject. References will be given to the original sources of the evidence upon which these laws are based, but a detailed historical account of the establishment of the laws will not be attempted, although some of them may only have been accepted after prolonged discussion.

(III.) A short statement of the hypotheses and of the partial or general theories of electrolysis which have been proposed and are still under discussion, and the experiments relating to them, including especially the following questions :—

- (*a*) What is an electrolyte ?
- (*b*) What are the ions in any given electrolytic decomposition, including the cases of mixed electrolytes ?
- (*c*) The Williamson-Clausius theory of dissociation.
- (*d*) Electro-chemical thermodynamics, including thermo-electric effects.
- (*e*) The theory of electric endosmose.
- (*f*) The theory of the migration of ions and of specific ionic velocities.
- (*g*) The numerical relations of electrical conductivity with other physical and chemical properties of the electrolytic substances.

(IV.) A discussion of the experimental methods and the apparatus used in the determination of numerical values used in the previous section.

(V.) An account of electro-chemical phenomena which are not generally included in the term 'electrolytic,' but which may be used to elucidate the electrolytic theories. In this section will be included certain phenomena connected with the passage of electricity through solids and gases, and the conductivity of flame.

(VI.) Electrolytic or electro-chemical phenomena which are not regarded as having a direct bearing upon electrolytic theories, viz. secondary actions, electro-capillary phenomena, irreciprocal conduction, electrostriction, and transition resistance.

Part I.

General Electrolytic Phenomena.

In order to analyse the actions taking place in electrolysis, we may imagine the electrolyte in the cell divided into three portions by two parallel partitions of porous non-conducting substance; the two end portions, the anode and the cathode vessels, contain the positive and negative electrodes respectively; the middle portion, while it allows the transmission of electricity through it, may be imagined protected from any change of composition which, in the absence of partitions, might be effected by diffusion, or mechanical transfusion, or convection currents of liquid. How far such an ideal partition is realisable in practice will appear later. The electrodes may be any electrical conductors, solid or fluid, alike or different. For a typical specimen we cannot regard an electrolytic liquid otherwise than as a mixture of solutions of chemical compounds, though the amount of all but one of the constituents of the mixture may be so small as to be regarded merely as impurities, which it would not even be possible to detect by ordinary chemical means. The remarkable sensitiveness of electrolytic properties to change, in consequence of the admixture of very minute portions of impurity, renders this necessary.

Thus Von Helmholtz has already said in his Faraday Lecture that he has detected the polarisation corresponding to the decomposition of a quantity of water of the order 1×10^{-11} gramme. And Gore [1] has shown that the effect of chlorine upon the E.M.F. of a Pt-Mg voltaic couple in distilled water is such that the presence of one part of chlorine in seventeen thousand million parts of water could be detected thereby. The neglect of considerations of this kind finds very remarkable illustration in the history of electrolysis. It is now generally known that the experiments upon very pure water, especially those of Kohlrausch,[2] have so far changed the views upon the matter that, whereas at one time water was regarded as the conducting part of a solution, pure water is now looked upon as probably not conducting at all. Kohlrausch obtained water the ratio of whose conductivity to that of mercury was $0{\cdot}71 \times 10^{-11}$ at 21·5° C., and its sensitiveness for small quantities of impurity approximated to that of the sense of smell, since when exposed in a room containing tobacco-smoke its conductivity doubled in three hours. The simplification that would be introduced by regarding the typical electrolytic cell as containing a perfectly pure chemical compound liquid cannot therefore be realised in practice, and any part of a theory which depends for its support on such an assumption must, for the present at any rate, be held in suspense.

When an electromotive force is made to act between the electrodes of such a cell as that described above, so that a current is shown in a galvanometer included in the circuit, the following actions take place:—

(*a.*) A part of the electrolyte is decomposed, the products of the decomposition are deposited at the electrodes, and these either (i.) are visibly set free, (ii.) unite with the electrodes, or (iii.) unite chemically with the solution in the anode or cathode vessel as the case may be, and in the

[1] *Proc. Roy. Soc.* June 14, 1888, vol. 44, p. 301

[2] Pogg. *Ann.* Ergz. B. 8, 1876, p. 1; Wied. *Elec.*

last two cases give rise to 'secondary' chemical products. These secondary actions are quite independent of the direct effect of electrolysis.

If we consider this chemical action more in detail, we may regard the electrolytic liquid as composed of a number of molecules, and the action will then be the separation of a number of these molecules each into two constituent parts or ions: these ions are deposited at the electrodes only. Considering a single molecule, the one part is deposited at the cathode, and is called the cation; the other part (or the corresponding part of a *similar* molecule) at the anode, and is called the anion. The terminology of the subject was introduced by Faraday ('Exp. Res.' Ser. VII. 1834). What is precisely to be understood by the 'molecule' which is decomposed is not yet clear. Even if we suppose the electrolyte a solution of a salt so pure that the decomposition of impurity could not in any case be detected, we cannot now say that all the molecules decomposed are similar. To take a definite instance, in a solution of sodium chloride the molecule decomposed may be the simple chemical molecule NaCl, or it may be a molecular aggregate of sodium chloride [n(NaCl)], or an aggregate of salt and water [n(NaCl), $m(H_2O)$], or some molecules of one kind and some of another may be decomposed. The primary results of the separation of the molecules, each into two parts, are the true ions, and are deposited at the electrodes. But, however complicated may be the molecules of the electrolyte which are regarded as individually decomposed, in cases in which there is visible deposit on the electrodes, or direct combination with the electrodes, the deposit or combination could have been produced by the decomposition of the simple molecules [NaCl] of salt in the solution.

(*b.*) The volume of the liquid in the cathode vessel increases; that in anode vessel diminishes. This phenomenon, which is known as electric endosmose, is attributed to the action of the porous diaphragms, and is regarded as independent of the more strictly electrolytic phenomena.

(*c.*) The percentage composition of the solution in the anode and cathode vessels is altered, generally unequally in the two, while that in the intermediate vessel remains unaltered. This phenomenon is usually attributed to the migration of the ions with unequal velocities through the solution, and is equivalent, if the ions be the result of decomposition of *simple* molecules, to a transfer of those molecules, which in the end are left in combination, through the body of the solution, in one direction or the other.

(*d.*) There is a rise in temperature of the liquid owing to the development of heat by the current, just as there would be in the case of a metallic conductor.

(*e.*) The deposit of ions upon the electrodes causes an electromotive force opposed in direction to the decomposing electromotive force applied. This E.M.F. of polarisation is in some cases sufficiently great to balance the latter and prevent the further flow of current.

The current may also be considerably reduced by the resistance of a layer of non-conducting material produced by the action of the ions on the electrodes.

(*f.*) Thermo-electric effects are produced at the junctions of the different substances in the circuit, including the junctions of metal and liquid.

Part II.

Laws and Principles generally Accepted.

(*a.*) *The electro-magnetic action of the current passing through an electrolyte is the same as if the electrolyte were replaced by a metallic conductor of the same size and shape, and of such resistance that it could be substituted for the electrolyte without altering the current in the rest of the circuit.*—This merely expresses the idea that the flow of electricity may be regarded as analogous to that of an incompressible fluid, even when an electrolyte forms part of the circuit, being either the fluid conductor of a battery cell or of a voltameter cell. The references quoted by Wiedemann (vol. i. p. 321) for this statement are: Wiedemann, 'Galvanismus,' I. Aufl. 1861, p. 97; Schiller and Colley, Pogg. 'Ann.' 155, 1875, p. 467; Cooke, 'Chem. News,' 40, 1879, p. 22; 'Beibl.' 3, p. 632; R. Kohlrausch, 'Pogg. Ann.' 97, 1856, p. 401.

The current may for some purposes be regarded as the flowing of positive electricity like an incompressible fluid round the circuit in the direction from anode to cathode, the quantity which crosses any section in unit of time measuring the current. For the body of the electrolyte, however, the language of the two-fluid hypothesis is considered by Von Helmholtz as more convenient, and it is usual to regard the current in the electrolyte as made up of the independent flow of equal quantities of positive and negative electricities in opposite directions. It will appear later that it is possible to form an estimate of the absolute rates at which the positive and negative quantities respectively flow, and that the absolute rates may be unequal; in that case the measures of the current at any section due to the flow in the two directions respectively will not be equal. But minute considerations of the disposal of the positive and negative electricity may lead to confusion (see Wiedemann, 2, § 1043); and evidently if we regard the current as a convective discharge, by redistribution of parts, along a single line of molecules with oppositely electrified sides, the current at any given section between two molecules will be due entirely either to the motion of positive electricity in one direction or of negative in the other, according to the position of the section; and in that case the quantities of positive and negative electricity actually engaged will be double of those required, if one is allowed to suppose that they pass each other instead of meeting each other.

It is not clear that we are justified in regarding the positive and negative electricities each as separate incompressible fluids continuous throughout the whole circuit, as suggested by Lodge ('B.A. Rep.' 1885); but this point may be more completely discussed in considering the theory of unequal migration of ions (Part III. § *e*).

(*b.*) *There are electrolytes in which conduction of electricity from the electrode to the electrolyte, and again from the electrolyte to the electrode, is entirely 'convective,'* in the sense that no electricity can pass into an electrolyte or out of it again without causing a deposit of a certain number of constituent ions where the current enters, and of an equal number of the remainders of the decomposed molecules (opposite ions) where it leaves the electrolyte, the weight of electrolyte decomposed being proportional to the quantity of electricity transmitted. This is included in Faraday's law, and is equivalent to saying that in certain electrolytes there is no conduction without chemical decomposition; and it may be expressed by the formula

$$W = K.E,$$

where W is the weight of electrolyte decomposed by the passage of the quantity E of electricity, and K a constant depending on the nature of the electrolyte.

I have worded the statement of this proposition in a carefully guarded manner; it certainly holds for a very large number of electrolytes, possibly for all. The proposition has been gradually evolved as the result of a large number of observations. Faraday (Exp. Res. ser. 8, § 970, 984, 1834) allowed a slight amount of conduction without chemical decomposition; and since that time the question has been much discussed, and the causes of the apparent metallic conduction traced. An account of the discussion is given in Wiedemann, vol. 2, p. 488, which is summed up as follows: 'According to all these experiments we must now accept that if once the conduction of currents through electrolytes is associated with their simultaneous decomposition, then, besides this electrolytic conduction, which follows strictly the electrolytic [Faraday's] law, no second metallic conduction of a part of the electricity takes place therein.' Von Helmholtz in Part III. of his 'Thermodynamics of Chemical Processes' (Phys. Soc. Translation, p. 79) says: 'If the two electrodes of a voltameter be charged and maintained at different potentials, electric forces corresponding to the slope of potential act within the fluid, driving + E to the cathode, − E to the anode. This movement of electricity never takes place, so far as we know, without a simultaneous motion of the ions of the electrolyte to which the + E and − E set in motion are attached'; and in the next page, 'I have myself succeeded in following out the proportionality between the electromotive force and the amount of condensed charge . . . . down to electromotive forces of 0·0001 Daniell.'

Von Helmholtz also expressed the same view in the Faraday Lecture, in which he announced that with an air-free cell therein described he had detected the polarisation produced during a few seconds by a current which would only decompose a milligramme of water in a century; and he went on to say: 'But even if the appearance of galvanic polarisation should not be acknowledged by opponents as a sufficient indication of previous decomposition, it is not difficult at present to reduce the indications of a good galvanometer to absolute measures and to calculate the amount of decomposition which ought to be expected according to Faraday's law, and to verify that in all the cases in which no products of electrolysis can be discovered their amount is too small for chemical analysis.'

Bouty (quoted by Lodge, 'B.A. Report,' 1886, p. 348), referring in particular to acidulated water, asserts, 'A liquid has only a single way of conducting electricity, whatever may be going on at the electrodes. The expressions "metallic conductivity" and "electrolytic conductivity" ought to disappear from science.'

Experiments on the decomposition produced in acidulated water by the induction of electrostatic charges are described by Wiedemann (2, § 544) and by Ostwald and Nernst ('Electrician,' 23, p. 300, 1889), who observed a bubble of hydrogen which would correspond to the decomposition of 4×10^{-10} gramme of water. Bouvet ('C. R.' 87, p. 1068) has found that the quantity of electricity necessary for decomposing a given quantity of water is independent of the pressure up to 200 atmospheres.

Thus it may fairly be allowed that acidulated water is one of the electrolytes for which this proposition is true.

It is also regarded as true for solutions of salts of silver, for which, according to Lord Rayleigh and Mrs. Sidgwick ('Phil. Trans.' 1884 (2), p. 411), every gramme of silver deposited upon an electrode corresponds to the passage of 84·82 C.G.S. electro-magnetic units of electricity; according to F. and W. Kohlrausch (Wied. 'Ann.' 27, 1886, p. 1), 84·53 such units. The proposition is probably equally true for all salt solutions, but the inference that it is true for all electrolytes is not yet substantiated, though evidence continues to accumulate in its favour. Thus Faraday ('Exp. Res.' 414, 691, 692, 1340) considered that fused HgI_2, PbF_2, and $HgCl_2$, conducted without any chemical decomposition, but Beetz (Pogg. 'Ann.' 92, 1854, p. 461) has shown that PbF_2 conducts in a normal electrolytic way; and J. W. Clark ('Phil. Mag.' 20, 1885, p. 37) showed that there was chemical decomposition in the conduction by the other two fused salts.

But Gladstone and Hibbert ('B.A. Report,' 1888, p. 347), in communicating to the Electrolysis Committee the results of experiments on alloys and solid sulphides, still make use of phrases such as 'the conduction was accompanied by considerable electrolysis'; 'the conduction was almost entirely non-electrolytic'; which would seem to imply that the practice of distinguishing between metallic and other conduction in the same substance is not yet entirely abandoned.

[See an extract of a paper by Barus [1] ('Electrician,' Dec. 21, 1888, p. 199) on supposed transition from metallic conduction to electrolytic conduction in gases, on passing through the critical point of the metal; also Lodge, 'B.A. Report,' 1885, p. 767.]

If it be allowed that the conduction of electricity into and out of an electrolyte is convective in the sense already explained, there will be no difficulty in accepting the next stage in the development of the idea, namely, that the conduction from point to point of the liquid is similarly convective; and, in fact, we arrive at the general statement that the redistribution of electrification, which constitutes an electric current through, or statical charge upon the surface of, an electrolyte, is accompanied by, and indeed consists in, the redistribution of ions carrying electric charges.

We may here also briefly consider the second part of Faraday's law, namely, that the same quantity of electricity produces in different electrolytes the separation of chemically equivalent amounts of ions. There is no doubt about the truth of the statement; it has been experimentally tested for some cases where it has a definite meaning, and has been shown to be true for fused and dissolved electrolytes, within the limits of error of determination of chemical equivalents or atomic weights,[2] and is, indeed, recognised as in some cases an accurate method of finding the ratio of chemical equivalents.[3] But there is attaching to it whatever uncertainty attaches to the meaning of the term 'chemical equivalent.' Everyone would

[1] *American Journal of Science*, Dec. 1888.

[2] Faraday, *Exp. Res.* 3, § 377; 7, § 783 (1833). Matteucci (*Ann. de Chim.* 58, 1835, p. 75). Becquerel (*Ann. de Chim.* 66, 1837, p. 91). Soret (*Ann. de Chim.* [3] 42, 1854, p. 257). Renault, *Ann. de Chim.* [4] 11, p. 137. Gray, *Phil. Mag.* 22, 1886, p. 389.

[3] For silver and copper, Shaw, *B.A. Rep.* 1886, p. 318. For zinc, Gladstone and Hibbert *Journ. Chem. Soc.* July 4, 1889, p. 443.

admit that if there are two electrolytic cells in series containing electrolytes A B, A′ B′, A and A′ being cations, B and B′ anions, the amounts of A and A′ or of B and B′ deposited by the same quantity of electricity are chemically equivalent; but for a given electrolyte, the specification of the ions into which it will be decomposed by the current is not always known, or even ascertainable; moreover, there are cases in which the elements have more than one chemical equivalent, so that it is not practicable to state this part of Faraday's law in more definite terms than those given above. The recent work on the subject will be considered in the answer to the question 'What are the ions?' in Part III. § *b*.

But there is no question of doubt when the electrolytes are fused or dissolved compounds of monad elements only, and there are many other cases of dyad and triad compounds in which the chemical equivalence of the ions is well recognised, and in all these cases Faraday's law in its complete form may be applied with confidence; and the final result is that with every monad atomic ion there is associated in electrolysis a certain definite quantity of electricity, positive or negative[1]; with every dyad atomic ion twice that amount, with every triad three times, and so on. And in all true electrolytes, the distribution of electricity is the distribution of these ions carrying their specific charges.

(*c.*) *The conduction of electric currents through electrolytes follows Ohm's law.*—It must be remembered that for metallic conductors it has been shown by Chrystal and Saunder that if the relation between electromotive force e and current i be represented by

$$e = ir\,(1 - hi^2)$$

then h is less than 10^{-12}, showing that for these Ohm's law is true with extreme accuracy. There are certain physical laws which, although originally discovered empirically, express as numerical relations necessary consequences of the nature of the physical quantities referred to in the laws. Thus Snell's law of refraction (expressing, as is now known, the ratio of velocities of transmission in two media) is not a law in which one expects further experimental investigation to detect a deviation from accuracy. Faraday's law is another illustrative example. The inverse square laws, which perhaps merely express the property of transmission in straight lines, are also laws which seem to be strictly true, and not empirical approximations. There is a difference in character between these and such as the gaseous laws, in which more refined apparatus and methods detect divergences from the apparent simplicity. Now Ohm's law for metals, being the most accurately verified of all laws, would seem to belong to the former class, and to be a necessary consequence of the nature of conduction itself. J. Hopkinson[2] suggests that the law asserts the principle of the superposition of the effects of electromotive forces in bodies in which the conduction is not complicated by residual charge, and it may therefore be regarded as a special case of the more general principle of superposition.[3] He divides the continuous effect of electromotive force on glass into four successive stages, and thinks that the same might hold if we could experiment fast enough for an electrolyte, the principle of superposition probably applying to all the continuously connected successive events.

[1] For the calculation of the amount of electricity on a monad atom see Lodge, *B.A. Rep.* 1885; Budde, Wied. *Ann.* 25, p. 562, 1885.

[2] *Phil. Trans.* 167, 1877, p. 614.

[3] *B.A. Rep.* 1886, p. 309.

The detection of any deviation from Ohm's law in an electrolyte would be of great interest, for it would probably indicate an important change in the nature of the conduction. From what has been said about Faraday's law we have concluded that the conduction in an electrolyte is of the same nature for different electromotive forces, and therefore no deviation from Ohm's law is likely to be detected. But if the nature of the ions changed with increase of current we should expect the fact might be indicated by a deviation from Ohm's law; and, conversely, if it be possible to increase the current to such a limit that Ohm's law no longer holds, some change in the nature of the conduction should be looked for.

Besides gases there are some bodies which do not follow Ohm's law. I am under the impression that a lead-pencil mark on ground glass does not. According to Braun,[1] psilomelane, iron pyrites, and copper pyrites do not, and, according to Quincke,[2] some of the liquids of high resistance—ether, CS_2, turpentine oil, rock oil, and benzene—are disobedient for electromotive forces of, say, 30,000 volts and upwards. When the divergence shows itself there are indications of electrolytic decomposition. Quincke also refers to observations on departure from Ohm's law in thin layers of gutta-percha, sulphur, paraffin, and shellac for small electromotive forces by Schulze-Berge,[3] and to anomalous conduction observed by himself.[4]

The direct verification of Ohm's law for copper sulphate has been pushed by Fitzgerald and Trouton[5] to the extent of determining, by Chrystal's method, that, for this salt, h (in the formula p. 192) is less than 3×10^{-6}. The maximum current employed was 10 ampères per square centimetre. The previous verifications are by Beetz[6] for zinc vitriol solution, by F. Kohlrausch[7] for dilute H_2SO_4, for E.M.F.s from $\frac{1}{20}$ to $\frac{1}{2}$ Grove cell for zinc vitriol solution, by Reinold[8] and Rücker for thin liquid films, and by E. Cohn[9] for H_2SO_4 and $CuSO_4$ solution (in reply to a paper by Overbeck[10]), using currents with periods of alternation between 100 and 25000 per second.

Some additional evidence in favour of the application of Ohm's law to conduction in electrolytes is derived from the very numerous measurements of the resistance of electrolytes. I am not aware that any of the many observers in this or other departments have suggested a variation of resistance with current, as an explanation of differences in the numerical values obtained for the specific resistance of the same solution, with the exception of Kopp[11] in some experiments on Joule's law.

The one point that remains to be settled is whether any experimental evidence can be found for the deduction from Maxwell's 'Theory of Light' that electrolytes, being transparent, should behave as dielectrics for rapidly alternating electromotive forces. There are two ways of approaching the question: (1) to find the length of the light-wave for which electrolytes are opaque; (2) to find the rapidity of electrical vibration for which the electrolytes cease to conduct. Nothing seems to have been done in No. (1); as to No. (2) Prof. J. J. Thomson[12] has found

[1] Pogg. *Ann.* 153, 1874, p. 556; Wied. *Ann.* 1, 1877, p. 95; 19, 1883, p. 340.
[2] Wied. *Ann.* 28, 1886, p. 542.
[3] *Verhandl. der Phys. Ges. zu Berlin*, 14, 1, 1886, p. 90.
[4] Wied. *Ann.* 10, 1880, p. 551.
[5] *B.A. Rep.* 1888, p. 341; 1886, p. 312; 1887, p. 345.
[6] Pogg. *Ann.* 125, 1865, p. 126; 117, 1867, p. 15.
[7] *Ibid.* 138, 1869, pp. 280, 370.
[8] *Proc. Roy. Soc.* 31, 1881, p. 524.
[9] Wied. *Ann.* 21, 1884, p. 646.
[10] Wied. *Ann.* 6, 1879, p. 210.
[11] *Beibl.* 10, 1886, p. 714.
[12] *Proc. Roy. Soc.* 45, p. 288.

that electrolytes still conduct when the rapidity of alternation is two hundred millions per second.

If there should be evidence to show that there is no rapidity of alternation for which electrolytes behave as dielectrics and no waves so long that electrolytes are opaque, we might take up Lodge's [1] third suggestion, that the number of molecules actually taking part in the conduction is too small to affect the properties of the substance in bulk, but this would have important bearings on the theory of conduction.

(*d.*) *The only immediate effect of the passage of the current upon the body of a homogeneous electrolyte is to alter its temperature, and the alteration of temperature takes place in accordance with Joule's law.*

There are two statements involved in this proposition. First, the chemical effects take place entirely at the electrodes: although the electricity is conveyed convectively through the electrolyte there is no change in the physical or chemical properties of the fluid in the intermediate vessel of the cell described in Part I. The electrolyte between the anode and cathode vessel produces the electro-magnetic effect corresponding to the current, but it gives no other evidence that a current is passing; it is the same fluid in the same condition as if no current were passing. This amounts to asserting a negative, and by it I do not intend to deny the possibility of some evidence of changed condition being ultimately discovered. Reinold and Rücker found no evidence of change of state in their films. Lord Rayleigh [2] has looked for an effect upon the power of transmitting light, but the result of his experiments is to show that in dilute sulphuric acid a current of one ampère per square centimetre does not alter the velocity of light by one part in thirteen millions, or fifteen metres per second. I have thought it possible that there might be a change in the absorption spectrum of the liquid during the passage of the current; but the spectrum is a complicated phenomenon, and no difference is visible in the cases I have tried. It is much to be desired that the change, if any, in the condition of the conducting fluid should be speedily brought to light, as the question has an important bearing on the dissociation theory. Secondly, Joule's law applies equally to electrolytes and metallic conductors. With the acceptance of Ohm's law, this does not seem really to imply more than is included in the first statement above. For if there is no change in the condition of the electrolyte, the only expenditure of energy upon it is that required to maintain the current, and the resistance is the amount of work required to maintain unit current; so Joule's law follows if the resistance is constant. If there were any chemical cling, as Lodge calls it, of the atoms in the molecules, the law could not be true; so if it be true we must give up the idea of polarisation in the interior of an electrolyte, and the idea of a finite electric force being required to separate a molecule into ions. A number of direct experimental verifications of Joule's law for electrolytes have been attempted by Joule,[3] by E. Becquerel,[4] by Jahn [5] for $CuSO_4+200 H_2O$ and $CuSO_4+150H_2O$ (current between ·106 and ·162 ampère) and for $ZnSO_4+200H_2O$ and $ZnSO_4+300H_2O$ (current strength between ·037 and ·05 ampère), and by Kopp [6] for $ZnSO_4$. In no case has any deviation from the law been detected.

[1] *B.A. Rep.* 1885, p. 768.
[2] *Ibid.* 1888, p. 341.
[3] *Phil. Mag.* 19, 1841, p. 274.
[4] *Ann. de Chim.* [3] 9, 1843, p. 54; see Wied. *Elec.* 2, § 482–486.
[5] Wied. *Ann.* 25, 1885, p. 49
[6] *Beibl.* 10, 1886, p. 714.

The only apparent evidence against the application of Joule's law to electrolytes is the 'innere Polarisation' observed by Du Bois-Reymond.[1] This phenomenon is, however, only exhibited in heterogeneous conductors, such as filter-paper and other porous bodies when moistened with a bad conductor like water. It is not shown when H_2SO_4, KI, or KHO is used, unless the porous body is a good conductor, as charcoal or cylinders of stiff glue containing brass filings. It may be explained by the division of the current between the fluid and the matrix, in the same way as the decomposition of $AgNO_3$ in a crack in a glass partition, observed by Grotthuss.[2]

For the theory of the relation between E.M.F. and difference of concentration of an electrolyte, see Von Helmholtz, 'Wissensch. Abh.' vol. 1, p. 840.

It is clear from what has been said above that the conduction of electricity through the electrolyte may be considered quite separately from the actions taking place at the electrodes. We are accordingly led to notice two main and almost independent divisions of the subject. The first of these relates to the transformations of energy incidental to, and represented by, the separation of ions, the secondary actions, the thermo-electric effects, the electromotive forces of polarisation at the electrodes. This part may be called the thermodynamics of electrolysis, while the second deals with the conduction of the current through the liquid, the mechanism of conduction or of resistance, and its relation to other physical properties. In this no transformation of energy takes place but the frictional generation of heat. The secondary actions may in time affect the nature of the electrolyte, and the other effects at the electrode alter the magnitude of the current; but primarily the two parts of the subject are independent.

Part III.

§ a.—*What is an Electrolyte?*

The complete answer to this question would imply the complete solution of the problem of electrolysis, just as in the theory of light the complete solution is the answer to the question, What is common light?

Putting the question more definitely—What must be the physical state and chemical constitution of a substance in order that the conduction of electricity through it may be attended with the decomposition of the substance into ions appearing only at the electrodes?

In order to show that a particular substance is an electrolyte, the chemical decomposition produced by the current must be demonstrated either by the separation and exhibition of the products, or by the E.M.F. of polarisation. On account of the sensitiveness of electrical instruments, the latter is the more delicate method; but the analogy between an electrolyte of high resistance and a leaky condenser is so close that the distinction between a dielectric and an electrolyte may sometimes be difficult to draw.

The liquids whose conduction is undoubtedly electrolytic vary very greatly in conductivity. To give an idea of the extent of the variation, I have compiled a rough table of conductivities of a number of liquids, conductors and non-conductors (the numbers taken mainly from Wiedemann's 'Electricität').

[1] Wied. *Elec.* 2, p. 780. [2] Wied. *Elec.* 2, p. 783.

TABLE I.—*Conductivities of Liquids referred to that of Mercury* $\times 10^{-8}$ *at* 0° *C.*

[Numbers marked with an asterisk are not to be regarded as final numerical results; they are introduced to indicate the order of magnitude of the quantities.]

Liquid	Conductivity referred to Mercury at $0° \times 10^{-8}$	Temperature coefficient	Observer	Remarks
$PbCl_2$ (fused)	25,000·*	—	F. Braun	
AgCl "	24,000·	—	W. Kohlrausch	at 600°C.
$NaNO_3$ "	11,500·*	—	F. Braun	
HNO_3 in water	7,330·	·014		solution of maximum conductivity at 18°C.
HCl "	7,174·	·0155		"
H_2SO_4 "	6,914·	·0162		"
KOH "	5,095·	·0225		"
KI "	4,100·	·0140	From Wiedemann	sp. gr. 1·70
NH_4Cl "	3,980·	·0155		" 1·078
$AgNO_3$ "	2,100·	·0211		" 2·18
NaCl "	2,016·	·0234		" 1·201
$KHCO_3$ "	1,100·	·0199		" 1·15
$CuSO_4$ "	440·	·0241		" 1·208
$C_4H_6O_6$ "	94·	·0192		solution of maximum conductivity at 18° C.
$ZnCl_2$ fused	86·*	—	F. Braun	
$CaCl_2$ in alcohol	83·	·0102	Fitzpatrick	
$C_2H_4O_2$ in water	15·2	·0174	From Wiedemann	solution of maximum conductivity at 18° C.
$HgCl_2$ "	3·91	·0249	Grotrian	5 per cent. solution
$HgBr_2$ "	·24	·032	"	·422 per cent. solution
Alcohol	·018	·018	Pfeiffer	
Ether	{·008* ·0025}	—	{Kohlrausch "	
Water at 2°·5 F.	·0071	—	"	
" at 14°C.	·0065	·035	Pfeiffer	
Benzene	·002*	—	W. i. p. 565	
$SnCl_4$	? ·0000001*	—		

The electrolyte of highest conductivity is fused lead chloride, and by taking solutions more and more dilute, we obtain without any breach of continuity electrolytes of less and less conductivity down to that of pure water or pure alcohol, and the resistance of these is of the same order as that of benzene, and even for these and other nearly insulating liquids, as ether and oil of turpentine, evidence of polarisation has been shown.[1]

It is clear, therefore, that the question of what constitutes an electrolyte must be considered quite apart from the specific resistance of the substances.

As to the physical properties of electrolytes, the majority of them are liquids, but there are certainly solids in which conduction is attended with decomposition. I may refer to a diagram by W. Kohlrausch (Wied. 'Ann.' vol. 17, p. 642), showing his observations on the salts of silver,

[1] Picker quoted by Von Helmholtz, Faraday Lecture, *Jour. Chem. Soc.* 39, p. 291.

in which the continuity of the numerical value of the conductivity of AgI and the mixture AgCl+AgI through their fusing points is very striking. The point of transition of AgI [1] from the amorphous to the crystalline state is also interesting, and is marked on the diagram. The conduction of these bodies below the fusing point is attended with chemical decomposition, but whether it is wholly or only partially of that nature is not demonstrated. The diagram also shows the results of Hittorf's observations on Ag_2S, which is decomposed by the current when solid; this body fuses at a red heat. Solid Cu_2S was likewise shown by Hittorf [2] to conduct electrolytically.

Plumbic chloride, bromide, iodide [3] also conduct, and glass [4] even at low temperature. Warburg and Tegetmeier [5] have shown that sodium penetrates quartz electrolytically.

But all solid compound bodies do not conduct electrolytically; those in the following table conduct metallically :—

TABLE II.—*Compound Bodies which conduct like Metals.*

Substance	Observer
Cuprous selenide, Cu_2Se	Hittorf
Cupric sulphide, CuS	,,
Stannic sulphide, SnS_2	,,
Argentic selenide, Ag_2Se	,,
Lead peroxide, PbO_2	
Manganese dioxide, MnO_2	
Argentic oxide, Ag_2O	
Magnetite	S. P. Thompson
Hematite	,,

There is also an increasing body of experimental evidence of electrolytic action on the passage of electricity through gases, particularly in the neighbourhood of electric discharge. These phenomena will be considered in Part V.

There are, however, no liquids, other than pure metals and alloys, which conduct electricity with the same facility as fused or dissolved electrolytes without electrolytic conduction. Faraday [6] considered that fused HgI_2, $HgCl_2$, and PbF_2 were liquids which were capable only of metallic conduction, but fused PbF_2 has been shown to conduct electrolytically by Beetz,[7] and electrolytic action has been proved to exist also in the other two cases by J. W. Clark,[8] but it is not yet clear whether the conduction in these cases is entirely electrolytic. If it should prove to be so, conduction in liquids may prove to be, as J. J. Thomson [9] suggests, of identical nature in metals and electrolytes.

While, therefore, it would be unwise to say that whatever conduction there may be through liquids of very high resistance is not electrolytic, the difference in the condition and constitution of substances from which

[1] See also a paper by Lehmann, Wied. *Ann.* 38, p. 396.
[2] Hittorf, Pogg. *Ann.* 84, p. 5, 1851.
[3] Helmholtz, Faraday Lecture. Gross, *Monatsber. der Berl. Acad.* 1877, p. 500.
[4] Wiedemann, *Elec.* i. p. 558.
[5] *Nachr. v. d. K. Ges. d. Wiss. Göttingen*, May 30, 1888.
[6] *Exp. Res.* vol. 1, pp. 691, 692, 1340, and 1341.
[7] Pogg. *Ann.* vol. 92, p. 452, 1854. [8] *Phil. Mag.* July 1885, p. 37.
[9] *Application of Dynamics to Physics*, p. 297.

arise the phenomena that one conducts freely with chemical decomposition while another is nearly a perfect insulator, still remains to be classified and, if possible, explained. The following is a list of some liquids which are practically insulators of electricity [1] :—

TABLE III.

Stannic chloride, $SnCl_4$	—
Fused zinc iodide, ZnI_2	(Faraday)
Pure water (probably)	(Kohlrausch)
Fused anhydrous chromic peroxide, CrO_3	(Hittorf, Wied. 'Ann.' 4, p. 374, 1878)
Sulphurous anhydride, SO_2	Faraday. Confirmed by Hittorf (l.c.)
Sulphuric anhydride, SO_3	
Carbonic anhydride, CO_2	
Boracic anhydride, BO_3	
Arsenic anhydride, AsO_3	
Nitrogen peroxide, N_2O_4	—
?Osmic peroxide, OsO_4	—
?Vanadic anhydride	Hittorf l.c.
Bromic iodide, BrI	„
Metallo-organic compounds	Bleekrode, Wied. 'Ann.' vol. 3, p. 178, Table 5.
C_2N_2	Bleekrode, l.c., Tables 6 and 7
CS_2	
C_2Cl_4	
C_2Cl_6	
CCl_4	
Hydrocarbons	
Haloid compounds of the alcohol radicles	
HCl	Gore. Bleekrode, l.c., Table 1
HBr	
HI	
H_2S	Bleekrode, l.c.
H_3As	
PCl_5	—
Anhydrous HF	Moissan, 'Beibl.' x., p. 715.
SCl_3	—
$SbCl_5$	—
SnI_4	—
Sb_2O_3 fused	—
Antimony oxychloride	—

On the other hand the following are electrolytic conductors :—

Fused MoO_3	Hittorf (l.c.)
Liquid NH_3	Bleekrode (Wied. 'Ann.' 3, p. 161, 1878) (probably impure, Hittorf, l.c.)
„ HCN	„
Fused urea	Dewar
Sulphides of alcohol radicles, chlorides, bromides, iodides of the organic acid radicles and their chlorine and bromine substitution derivatives	Bartoli, 'Beibl.' 11, p. 160

The effect of physical state upon the insulators does not seem to affect their conductivity. $SnCl_4$ does not conduct at its boiling-point at ordinary pressure. According to Bartoli, benzene insulates up to the critical temperature; methyl alcohol conducts better and better up to the same and from thenceforward the gas insulates.

A cursory survey of Table I. will show that the temperature co-

[1] See also Bartoli (*Beibl.* vol. 11, p. 159) on the conductivity of solutions of the alcohols in benzene, &c.

efficients of all the electrolytes are of the same sign and of the same order of magnitude. Probably all electrolytes have temperature coefficients of the same sign, and this may have to be explained, but it does not help towards classification, for some alloys[1] have a positive coefficient. Moreover, according to Arrhenius, the sign of the temperature coefficient may be reversed at higher temperatures for a number of electrolytes of low conductivity (see p. 223).

According to Kohlrausch,[2] electrolytes must be mixtures. This is supported by the observations upon the effect of mixing two non-conductors as H_2O and HCl, which together form good conductors. And, perhaps, we should be justified in regarding whatever conducting power there may be in any pure sample of a single liquid as being due to the presence of impurity. The conductivity of mixtures of water and alcohol have been carefully investigated by Pfeiffer,[3] and from his curve it is clear that certain percentages of mixture have higher conductivity than either water or alcohol.

If this is to be regarded as a satisfactory definition of an electrolyte, the converse proposition, that a liquid will conduct if it be a mixture, should also hold. That is to say, in order to make one of the liquids given in Table III. conduct, all that is necessary is to mix it with some other substance. Mr. W. Coldridge[4] has examined from this point of view the effect of mixing various substances with $SnCl_4$, and has found that whereas the absorption of a small quantity of dry HCl gas produces a liquid which has very slight conducting power and shows galvanic polarisation, platinum chloride or chloroform can be mixed with the tin chloride without producing any conducting power. Moreover, the tin chloride absorbs considerable quantity of dry H_2S gas, which gives a yellow liquid insulating apparently as completely as the tin chloride itself, and at the same time no precipitation of SnS_2 occurs; but the addition of a minute quantity of water or alcohol to the mixture determines at once the precipitation of the tin sulphide and at the same time the conduction through the liquid. There seems to be a wide field for useful experiments in this direction, with the primary object of determining what is the nature of the special kind of mixture which causes conductivity and what are the ions when such a conducting mixture is produced. The fact that mixture alone is not sufficient to account for electrolytic action may be to some extent inferred from the fact that no evidence of decomposition can be observed in the conduction of electricity through alloys.[5]

Hittorf,[6] in his valuable survey of the history of electrolysis, maintains the proposition 'Electrolytes are salts'; but, p. 401, he says, 'As from chemical phenomena no sharp distinction can be drawn between salts and non-salts, so it is with the distinction between electrolytes and insulators.' Hittorf's definition of a salt[7] is a compound which by double affinity exchanges its constituents with those of another recognised electrolyte, the ions of the respective compounds being those constituent parts which take part in the double exchange. Upon this definition Professor G. Wiedemann remarked at the B.A. Meeting, 1887 ('Report,'

[1] Von Aubel, *Proc. Phil. Soc.* vol. 9, p. 133.
[2] *Gegenwärtige Anschauung*, pp. 10 and 17; Pogg. *Ann.* 159, p. 271, 1876.
[3] Wied. *Ann.* 25, p. 232, 1885.
[4] *Phil. Mag.* vol. 29, p. 383, 1890.
[5] See *B.A. Report*, 1887, p. 341.
[6] Wied. *Ann.* 4, p. 374, 1878.
[7] Pogg. *Ann.* 106, p. 561, § 65.

p. 347), 'This is not generally true. First, we have certain bodies which seem not to be decomposed by the current, though they exchange their elements with those of other compounds which are electrolytes. Take, for instance, anhydrous hydrochloric acid. It does not conduct. Nevertheless, as Dr. Gore has shown, if you put it upon carbonate of lime the carbonic acid is chased away and chloride of calcium is formed. And, to give another example, the chloride of propyle is a non-conductor; nevertheless, when you treat it with bromide or iodide of silver the chloride gets changed into bromide or iodide. With just reason you may object that this is no proof, for perhaps the chloride of propyle is only a very bad conductor, therefore the current does not pass in a sensible way and we cannot observe the decomposition. In this respect we may refer to the researches of Mr. Bleekrode in Holland, and Mr. Bartoli in Italy.

'But, on the other side, we find well-known electrolytes exchanging their ions with elements of other compounds which, without any doubt, are not their ions. So, for instance, chlor-acetic acid ($CH_2ClCOOH$) or the ethylic ether of this acid, and iodide of potassium exchange between each other the chlorine and iodine, though assuredly the ions of chlor-acetic acid are not Cl and CH_2COOH, but CH_2ClCOO and H.' (See also Wiedemann, 'Elec.' vol. 2, p. 926, and Lodge, 'B.A. Report,' 1885.)

If we adopt the dissociation hypothesis we may say that an electrolyte is a substance part of which is in a state of dissociation, each dissociated molecule being resolved into two parts, which form the ions in electrolysis. It remains to be considered whether there is any means of finding out (otherwise than by conductivity) whether there is any such dissociation.

The processes of chemical reaction are, however, brought by the dissociation theory into close connection with electrolytic action, so that Hittorf's classification can only be distinguished from the definition based on dissociation by the consideration that the latter goes a step further and explains and accounts for Hittorf's empirical generalisation. The case of chlor-acetic acid and others similar are considered by Ostwald, and cause him to extend the dissociation hypothesis in order to include them (see below, p. 220).

There remains, therefore, the definition forming the fundamental hypothesis of the dissociation theory, viz., that an electrolyte is a substance which contains some compound in a state of partial or complete dissociation. It is upon this hypothesis that a great deal of recent work in electrolysis has been based, and nearly all the observed phenomena of electrolysis have been deduced from it. What the precise nature of the dissociation is may not be clear. The provisional hypothesis regards the dissociation of a compound in an aqueous solution as the resolution of the molecules of the compound into atoms or their chemical representatives which form the ions in electrolysis. Large strides have been made towards the formation of a mechanical theory of the electrolysis of solutions on this basis, some account of which will be given below. What is still wanting for the completion of the theory, besides the explanation of small numerical differences between calculated and observed results and the development of its extension to include the exceptional cases mentioned above, is the investigation of the mode in which the solvent acts in producing the necessary dissociation without itself being appreciably resolved. That may no doubt be forthcoming when the actions of different solvents have been observed; in the meantime it is interesting to note that the definition of the electrolytic property by the dissociation of the electrolyte seems applicable not only to liquids but also to solids [1] and gases.[2]

§ b.—*What are the ions in any Electrolytic Decomposition?*

In Part II., Section *b*, we have seen that the process of conduction through an electrolyte consists in the motion of ions in opposite directions, each carrying a definite charge of electricity. It is a matter of great interest to identify the ions in any particular case, and in the years following Faraday's researches in electrolysis attempts to identify ions by the methods of chemical analysis were very numerous, and the interest in them was increased by the fact that the results arrived at were entirely opposed to the Berzelius theory of salts. This department of the subject is most conspicuously represented by a series of well-known papers by Hittorf, Pogg. 'Ann.' 89 p. 177, 98 p. 1, 103 p. 1, 106 p. 337, and p. 513 (1853–59).

The ions are deposited at the electrodes, where they are either set free or take part in secondary actions, and the first step towards the identification of the ions is to determine the primary chemical result of electrolysis from the final results which are due to secondary actions. Thus when a solution of KHO is electrolysed the obvious products set free are H and O, but the analysis of the liquid shows that both these products are secondary, and are due to the action of the primary products, K and HO respectively, upon water.

In order to determine the primary results of electrolysis from the secondary products, the division of the cell ideally represented in Part I. has been adopted, but the simple divisions there mentioned as used by Daniell and Miller do not serve the purpose of ideal separation; the arrangements necessary for this purpose are described in Wiedemann's 'Electricität,' 2, § 549. Hittorf's arrangements are described in the same volume, § 550, and an apparatus used recently by Loeb and Nernst is figured and described in p. 950 of vol. 2 of the 'Zeitschrift für phys. Chem.'

It might be supposed that the results of the analysis of the liquid contained in the anode and cathode vessel respectively would give the amount and nature of the decomposed compound, and the amount and nature of each of the products, and hence that the ions would be statistically determinate; that is, without giving any information as to whether all the ions were of the same kind or not, a result would be obtained which would strictly represent the average process. According to the general view, however, chemical analysis fails to give this conclusive evidence, the original electrolytic process being complicated by electric endosmose, and the unequal dilution in solutions, mentioned in Part I. (*b*) (*c*), as the following example will show:—

In the electrolysis of a solution of copper sulphate containing 3·793 grammes of copper in 100 c.c. of solution, while one gramme equivalent ($\frac{1}{2}$ Cu) of copper is being deposited in the cathode, the total gain of copper in the cathode vessel, taking account both of the deposited and the still dissolved metal, is ·75 of an equivalent, and

[1] Van 't Hoff, 'Ueber feste Lösungen und Moleculargewichtsbestimmung an festen Körpern,' *Zeitschr. für ph. Chem.* 5, p. 322, 1890.

[2] J. J. Thomson, *Phil. Mag.* 358, 1890.

the volume of the liquid in the cathode vessel increases by $11{\cdot}09 \times 37$ c.c.,[1] so that the amount of water transferred is $11{\cdot}09 \times 37 \times {\cdot}9/18$ gramme molecules. If we trust to the results of the chemical analysis solely to identify the ions we must assume that the molecule decomposed is of a complex nature, so that the decomposition takes place according to the following scheme:—

$$\text{Cu}\,m(\text{CuSO}_4)n(\text{H}_2\text{O})\,;\ \text{SO}_4\ m'\ (\text{CuSO}_4)\ n'\ (\text{H}_2\text{O}).$$

If now we assume that of the molecules decomposed equal numbers are taken from the anode and cathode vessels, we can arrange the gains and losses as follows:—

Cathode vessel (1 gramme equivalent of copper deposited).

Loss. $\frac{1}{4}$ gramme molecule decomposed.
i.e., $\frac{1}{4}\ n\ (1+m+m')\text{Cu}$
and $\frac{1}{4}\ (n+n')\text{H}_2\text{O}$.

Gain. $\frac{1}{2}$ gramme molecule of the cation.
i.e., $\frac{1}{2}\ \text{Cu}\ m\ (\text{CuSO}_4)\ n\ (\text{H}_2\text{O})$
i.e., $\frac{1}{2}\,(m+1)\text{Cu}$
$\frac{1}{2}\ n\ \text{H}_2\text{O}$.

Hence the net gain of Cu is—

$$\tfrac{1}{4}\ (1+m-m')\text{Cu}={\cdot}75\times\tfrac{1}{2}\text{Cu}\ . \qquad . \qquad . \qquad . \quad (1)$$

whence

$$m-m'={\cdot}5$$

and the net gain of water

$$=\tfrac{1}{4}\ (n-n')\text{H}_2\text{O}=\frac{1{\cdot}1}{2}\times 37\text{H}_2\text{O} \qquad . \qquad . \qquad . \quad (2)$$

$$n-n'=2{\cdot}2\times 37.$$

Even on this supposition, therefore, the chemical analysis would not completely determine the average composition of the molecules decomposed; only the differences (m—m') and (n—n') are determinable. We can, however, assign a formula to the simplest molecule that would give the observed result by assuming that the lesser of the two m, m' and of n, n' respectively are zero; thus in the case above, assuming that $m'=0$ and $n'=0$, we get $m={\cdot}5$ and $n=81{\cdot}4$.

The average molecule in this case would be approximately [2]

$$\text{Cu},\ \tfrac{1}{2}(\text{CuSO}_4),\ \frac{163}{2}\text{H}_2\text{O}/\text{SO}_4$$

or getting rid of fractions

$$\text{Cu}_2(\text{CuSO}_4)163\text{H}_2\text{O}/(\text{SO}_4)_2.$$

This indicates the extent to which the inferences from chemical analysis could be pushed. It is evident on reference to the table given in Wiedemann, 2, p. 592, that the average molecule would be different for different degrees of dilution which would alter the numbers on the right-hand side of equations (1) and (2). It appears from the table referred to, that if

[1] Wied. *Elec.* 2, p. 592.

[2] In a paper in the *Proc. Camb. Phil. Soc.* (Nov. 1889) the complex molecule is erroneously calculated in consequence of my having misunderstood Wiedemann's data.

the alteration due to the increase of volumes in the cathode vessel be separately allowed for, the decomposed molecules for different strengths of solution would come out very nearly the same, and hence a great simplification would result. This view, to some extent on the ground of the probable identity of ions in solutions of different strengths, is in fact adopted, and the change of volumes regarded as a separate phenomenon due to the diaphragm and called electric endosmose. Separating this we get for the decomposed molecule

$$Cu_2(CuSO_4)/(SO_4)_2\,;$$

in other words, the complex molecule decomposed consists of an aggregate of $CuSO_4$ molecules of which the electrolysis separates a portion only of the constituent atoms.

But further, the nature of the decomposed molecule would still be somewhat different for different degrees of dilution, for the dilution of the liquid round the cathode only becomes constant when the degree of dilution passes a certain limit. However, this also can be explained on the assumption of the simplest possible molecular decomposition, that of $CuSO_4$ into Cu and SO_4, by attributing the alteration with the concentration of solution to the migration of molecules of salt through the solution produced by the motion of the ions with unequal velocities. A separate section is devoted to this theory, so that it will suffice here to point out that its introduction reduces the electrolysis to the simplest possible form, namely, the resolution of a single molecule ($CuSO_4$) into atoms or their equivalents, viz., Cu and SO_4. As this is the hypothesis upon which the dissociation theory is based, but little objection arises on that score, but it should be borne in mind that although this resolution into atoms or atomic equivalents is the simplest possible, and has not met any facts that it is definitely incompetent to explain, yet it is only one of many more complex arrangements that might be suggested, and it is not yet clear by any crucial experiment whether simplicity or complexity is the rule observed by nature in the process of electrolysis. The following paragraph suggests one reason in favour of complexity.

The phenomena that are exhibited in a battery cell, consisting of electrodes of different nature in a liquid or in two liquids, are paralleled by corresponding phenomena exhibited with two similar electrodes in solutions of different strengths. The electromotive force of polarisation in the first case is represented in the second by an electromotive force resisting or promoting the alteration of strength of solution; and the heat of chemical action at the electrodes, part of which goes to produce the electromotive force, is represented by the heating effect of dilution of the solution.[1] There seems, on the ground here mentioned, reason for thinking that, in solutions which are not infinitely dilute at any rate, the migration of the ions may be a part of the primary electrolytic process, and indicate a corresponding complexity of the ions.

It may further be remarked that Bouty classifies salts into normal and abnormal ones. Those of the former class tend to closer equality of molecular conductivity in extreme dilution, and they are characterised by having a migration constant equal to ·5 for each ion, that is to say, they produce no alteration of concentration in the two vessels, or the decomposed molecule as directly determined by chemical analysis is a simple

[1] See papers by Moser, Wied. *Ann.* 3, p. 216, 1878.

one, or at least the same number of molecules of the salt are attached to the anion and cation respectively.

There is a certain amount of evidence for the existence of molecular aggregates in electrolytic solutions. Dr. E. Wiedemann ('B.A. Report,' 1887, p. 346) has examined the conductivity of copper-chloride solution at different temperatures from this point of view. The solution is specially interesting, because it changes colour with temperature, and the colour change is probably due to a change in the state of hydration. The conductivity increases nearly at a constant rate up to 60°, and beyond this point the rate rapidly diminishes, and therefore indicates that the conductivity of salts varies with their degree of hydration.

Helmholtz (Faraday Lecture, p. 289) says that it is possible that the majority of molecules in SO_4H_2 may be divided into SO_4 and H_2, some of them on the other hand into SO_4H and H. This would account for an alteration in the apparent velocity of hydrogen at different concentrations, for in the latter case some of the hydrogen would be carried backwards.

Bouty,[1] also discussing the conduction of H_2SO_4, says, 'One does not see how to explain a variation of this kind except by a change in the nature of the electrolyte (*i.e.* of the dissolved hydrate).' By making the hypothesis which Bourgoin made, that the hydrate really decomposed by the current was $S_2O_66H_2O$, Bouty considers that the anomaly of electrolysis, as expressed by Hittorf's values of n, and also that of conductivity, is explained. Hydrochloric acid is in much the same condition as sulphuric acid; it conducts as if its molecules contained three equivalents of basic hydrogen. Other remarks of a similar bearing might also be quoted.[2]

The electrolysis of strong solutions of CdI_2 in alcohol has been accepted on all sides as involving the decomposition of complex molecules.

Moreover, Arrhenius, in a letter to Lodge (May 17, 1886), 'British Association Report,' 1886, p. 311, suggests the formation of double molecules and treble molecules in concentrated solutions.

Crompton [3] has sought to prove the relation between hydrates existing in sulphuric acid and the conductivity of solutions by plotting the second differentials of the conductivity-concentration curves, and obtaining the result as a series of straight lines. The line of argument is that taken by Mendeleef in discussing the hydrates of alcohol and sulphuric acid by plotting the first differential of the density-concentration curves, but it is pushed a stage further. The method, however, is a somewhat uncertain one, and has been called in question. See Pickering 'Zeitschr. für phys. Chem.' vol. vi. p. 10, also 'Chem. Soc. Journ.' 1890, p. 64. It is liable to represent in a foreshortened way small irregularities of the original curves, which may, indeed, have a corresponding experimental basis; they may also depend merely upon errors of plotting of the original curve.

Whatever evidence there may be for the existence of aggregates in comparatively strong solutions affecting the conductivity, it must be remembered that it is not clear that the electricity is carried by the aggregates. It is possible that the solution may contain a number of dissociated

[1] *Ann. de Chim.* [6] 3, p. 481, 1884.

[2] See for instance Bouty, *C.R.* 104, p. 1789, 1887; and especially for the electrolysis of cadmium salts, see Werschoven, *Zeitschr. f. ph. Chem.* vol. 5, p. 481.

[3] *Jour. Chem. Soc.* 53, p. 116, 1888.

molecules as well as molecular aggregates, and that while the colour of the solution and a number of other properties depend upon the latter, the electricity may be conveyed by the former alone. It might even be suggested that if the temperature coefficient of absorption of a coloured solution were determined, it would be found to be closely related to the temperature coefficient of conductivity, and when allowance was made for the change of viscosity it might furnish the temperature coefficient of dissociation.

An interesting point in connection with the determination of the ions is the question whether the ions are all of one kind in an electrolytic solution; in other words, whether the water conducts, or all the current is carried by the molecules of the dissolved salt. If an electrolyte be a mixture, as of HCl and H_2O, do both compounds take a share in the conduction, or one only? Lodge ('Brit. Assoc. Rep.' 1885) argued strongly in favour of a division of the conductivity between salt and solvent, and founded a theory of migration on that hypothesis; but the experimental evidence seems to have left the subject in the following state.[1] It is possible to obtain water with a very high degree of insulating power, but, when it is pushed to the extreme limit, it is impossible to tell whether the conduction is due to water molecules or undetected impurity. In dilute solutions the increase of conductivity which is conferred upon the water by the addition of a small quantity of salt is due to the added salt alone, and the conductivity of a dilute solution containing the added salt may be deduced from the observed conductivity of the solution by subtracting the conductivity of the water of which the solution was made; in other words, conductivity by water molecules forms no part of the added conductivity due to the salt.[2] Thus water is regarded as a body of a special kind, which dissociates other salts and makes them conduct, but itself carries the current to no appreciable extent.

The resulting chemical products are certainly different for different values of the current density. If a dilute solution of copper sulphate be subjected to electrolysis under the effect of a very high electromotive force, bubbles of hydrogen speedily make their appearance at the cathode, and it has been supposed that there is a limiting value of the current density beyond which the current ceases to traverse the salt solely, and an appreciable amount passes through the water. C. L. Weber, 'Zeitschr. für phys. Chem.' vol. 4, p. 182, 1889, has employed this phenomenon to determine the absolute velocity of the ions. It may, however, be explained by the continued impoverishment of the solution in the neighbourhood of the cathode; and, in fact, if the electrolysis be continued for some time between platinum electrodes, the whole of the copper may be abstracted from the solution.

I have tried myself to ascertain whether the water took part in the conduction, by interposing a very dilute solution of copper sulphate between two much stronger ones, so that, if the water conducted, a layer of copper hydrate would be formed at the junction between the strong

[1] The discussion has been somewhat lengthy. Finally Kohlrausch has admitted that an experiment of Faraday's may possibly be explained satisfactorily by attributing a minute conductivity to the solvent. See Wied. *Elec.* 2, § 583; Kohlrausch, Wied. *Ann.* 26, p. 161; Arrhenius, *Brit. Assoc. Rep.* 1886, p. 311; Hermann, *Beibl.* xi. p. 831.

[2] F. Kohlrausch, Wied. *Ann.* 26, p. 190.

anode solution and the dilute solution. But I found that with the electromotive force at my disposal (50 volts) I was unable to determine any such layer of hydrate. The experiments were, however, not conclusive, for the hydrate is to a certain extent soluble in copper sulphate; overlooking this defect, the dilution seemed so to diminish the current as to make it weak enough for the sulphate molecules to carry it.

The rough agreement of Weber's results with the values of ionic velocities deduced by other methods is inconclusive, for the impoverishment of the solution would be itself dependent upon the ionic velocities, and hence the results deduced from the limit of current density would depend on the velocities—directly, upon the one hypothesis, and indirectly, upon the other.

Summing up the results of this section, so far as regards a fused electrolyte or the solution of a single salt, we may say that the ions have hitherto been determined from the results of the chemical analysis of the liquid in the anode and cathode vessel, with the tacit understanding that the electrolysis shall be regarded as that due to the resolution of single molecules into ions which are atoms, or their chemical representative radicles, unless the observations are such as to make such a view entirely untenable, even when the dilution is referred to unequal motion of the ions and not to complex molecular decomposition. Thus every chemical determination of the ions should imply a determination of the constant of migration; and when the dilution at one electrode is so rapid that to apply the hypothesis of unequal ionic motion successfully would require us to assume the velocity of one ion to be negative, that is, that the ion would have to be moved against the electrical forces acting upon it,[1] then the decomposed molecule may be regarded as compound; one ion is assumed to have associated with it one or more molecules, as may be necessary, of undecomposed salt. Thus a critical consideration of the ions in electrolysis leads us to the question of the migration of ions. There are, however, cases in which the ions corresponding to the simple molecular decomposition can be comparatively easily inferred. The results of a number of determinations of ions are given in the table on the next page (Table IV.).

A confirmation of the results obtained may be derived from the electrolysis of solutions in series, in which case the anion of one solution combines with the cation of the adjacent one. The results exhibited in the table show the amounts of the respective ions corresponding to the deposition of one equivalent of hydrogen in a voltameter, so that they may be also regarded as showing the application of the second part of Faraday's law.

One warning must be given about such determinations. In order to determine both the ions, both the anode and cathode vessel must be separately analysed. The analysis of one alone is not sufficient. For a salt such as Na_3PO_4 may be decomposed by solution into NaH_2PO_4 and Na_2HPO_4, and the electrolysis be different from what it would be if the deposition of Na were established, and the second ion inferred from the composition of the original salt. I do not think that all the results quoted in the table have been subjected to minute criticism from the

[1] The force upon an atom or group of atoms carrying a charge $+\epsilon$ would be $\epsilon\frac{dV}{dx}$, when $\frac{dV}{dx}$ is the slope of potential per unit of length from anode to cathode, in the direction *towards* the cathode.

Table IV.—*Ionsas deduced from the Results of Chemical Analysis, referred, if possible, to the Resolution of a simple Molecule into Atoms or their Chemical Representatives.*

Electrolyte	Solvent	Anion	Cation	Authority
KHO	Fused	HO	K	Janeczek, 'Wied.' § 580
SiO_2	,,	—	Si	§ 581
As_2S_3	,,	S	As	§ 581
Cu_2Cl_2	,,	Cl	Cu	Buff, 'Wied.' § 582
$Al_2Cl_6 + NaCl$	,,	$AlCl_3 + Cl$	Na	Buff and Hittorf, 'Wied.' § 582
MoO_3	,,	MoO_2	O	—
$K_2Cr_2O_7$	,,	$CrO_3 + \frac{1}{2}O$	K	—
H_2SO_4	—	$\frac{1}{2}(SO_4)$	H	'Wied.' § 608; Gee & Holden, 'Proc. Phys. Soc.' May 26, 1888
HgI_2	Fused	I	$\frac{1}{2}(Hg_2I_2)$?	Clark, 'Phil. Mag.' July 1885, p. 37
HNa_2PO_4	In water	$\frac{1}{2}HPO_4$	Na ?	Daniell & Miller, Hittorf, 'Wied.' p. 532
Na_3PO_4	,,	$\frac{1}{3}PO_4$	Na ?	,, ,,
$Na_4P_2O_7$	,,	$\frac{1}{4}P_2O_7$	Na ?	? See Ostwald, 'Zeitschr. für phys. Chem.'
NaH_2PO_4	,,	H_2PO_4	Na ?	Daniell and Miller
KH_2PO_4	,,	H_2PO_4	K ?	,, ,,
H,Na,NH_4,PO_4	,,	HNH_4PO_4	Na	,, ,,
H_2KAsO_4	,,	H_2AsO_4	K	,, ,,
KSCN	,,	SCN	K	,, ,,
$K_3Fe(CN)_6$	,,	—	K	,, ,,
$NaNH_4C_4H_4O_6$	,,	—	Na	,, ,,
$(UO_2)Cl_2$	,,	Cl	$\frac{1}{2}(UO_2)$	,, ,,
$KAg(CN)_2$	,,	$Ag(CN)_2$	K	,, ,,
Na_2PtCl_6	,,	$\frac{1}{2}(PtCl_6)$	Na	Hittorf, Wied. 'Ann.' vol. 4, p. 374.
K_2CdI_4	,,	CdI_4	K	—
H_2S	,,	$\frac{1}{2}S$	H	Berthelot, 'Wied.' p. 540
KHO	,,	HO	K	'Wied.' p. 542
Morphin	,,	Cl	$H + C_{34}H_{19}NO_6$	'Wied.' p. 925
$H_2C_2O_4$	,,	$\frac{1}{2}(C_2O_4)$ (not CO_2)	H	,, ,,
$SnCl_2$	,,	Cl	$\frac{1}{2}Sn$	Becquerel, Wied. Elec.' § 601
AgCl	In NH_3 solutn.	—	Ag	,, ,,
$FeCl_2$	In water	—	$\frac{1}{2}Fe$	,, ,,
Cu_2Cl_2	In HCl	—	Cu	,, ,,
$SbCl_3$	,,	—	$\frac{1}{3}Sb$	,, ,,
$SbCl_3$	Fused	—	$\frac{1}{3}Sb$	,, ,,
Cu_2O	In NH_3 solutn.	—	Cu	,, ,,
CuO	,,	—	$\frac{1}{2}Cu$	,, ,,
$Cu_2S_2O_3$	In water	—	Cu	,, ,,
CuN_2O_6	,,	—	$\frac{1}{2}Cu$	,, ,,
$2PbNO_3H_2O$	,,	—	Pb	,, ,,
$4PbNO_3,3PbH_2O$	,,	—	1·75Pb	,, ,,

point of view here indicated. The table is, in fact, merely a summary of results as quoted by Wiedemann ('Elec.' vol. 2), and represents the ions as indicated by the older experiments in electrolysis. The subject has not been specifically dealt with recently, but the modern work bearing on it will be brought under review in the section on the migration of ions.

It must further be remembered[1] that in the case of acids (where one of the ions is hydrogen) it is not possible by quantitative analysis to draw a distinction between the resultant effect of the motion of the positive ion and the deposition on the electrode. The whole result of the electrolysis, as far as the cathode vessel is concerned, is to develop a certain amount of hydrogen, and possibly increase or diminish the amount of free acid. Hence the distinction between primary and secondary development of the hydrogen fails.

Some light might be thrown on the problem of the identification of the ions by the consideration of the heat-equivalents of the chemical action at the electrodes which should, if thoroughly understood, furnish evidence of distinction between the primary results of electrolysis and the secondary effects at the electrodes. I have already alluded to one case, namely, that of the representation of the heat-equivalent of the dilution of a solution as an electromotive force, being possibly evidence of the complexity of the ions; but taking the evidence that I have been able to consult and arrange, it does not appear that the thermodynamic theory of electromotive force is sufficiently far advanced for it to be used with confidence as a means of determining the ions in electrolysis.

We pass on now to the consideration of the ions in mixed solutions. In this case the substances set free at the electrodes are more liable to be due to secondary actions than in the case of a solution of a single salt, so that for some time it was supposed that the ions depended on the current density. An account of the earlier observations on this subject is given in Wiedemann, 'Elec.' 2, p. 593, from which it appears that at all current densities the current is divided between the two dissolved salts, but the ions due to one of them react upon the solution, and thus is explained the actual appearance of only one set of ions.

Of recent work we may refer to S. P. Thompson's paper on the Electro-Deposition of Alloys ('Proc. Roy. Soc.' 1887, p. 387), and to a paper by Arrhenius on Isohydric Solutions (Wied. 'Ann.' vol. 30, p. 51, 1887, and 'British Association Rep.' 1886, p. 315).

By this latter paper we may infer (from the fact that the conductivities of certain mixtures are the sum of what would be the conductivity of each if the other were removed) that the presence of the one salt in solution does not affect the partial conductivity of another salt in the same solvent, provided that the concentrations are of certain values, and hence that the two salts are resolved into ions independently. Salt solutions which are of such concentration that, when mixed, the conductivities may be regarded as the algebraic sum of the conductivities of each salt separately, are called by Arrhenius isohydric solutions. And the general law is established that solutions which are isohydric with the same solution are isohydric with each other, and thus a table of isohydric solutions formed. Bender, in two papers, Wied. 'Ann.' 22, p. 179, 1884, and Wied. 'Ann.' 31, p. 872, 1887, publishes the results of a number of

[1] Hittorf, Wied. *Ann.* 4, p. 410, 1878.

observations on mixed solutions, but the results are not arranged in the same form as those of Arrhenius, and the isohydric law is at any rate not apparent. (See also Ewing and Macgregor for resistances of mixtures of $ZnSO_4$ and $CuSO_4$ solutions, 'Trans. R.S.E.' 27, p. 51, 1873, and Bouty, 'C.R.' 104, p. 1699, 1887, 'Beibl.' 11, p. 650.) Bouchotte, Paalzow, and Klein are also referred to by Arrhenius.

§ c.—*The Williamson-Clausius Hypothesis.*

We have seen in Part II. *b* (p. 189) that the transfer of electricity through an electrolyte is convective. If we consider, on the well-known hypothesis of Grotthuss, a chain of molecules of the electrolyte connecting the anode and cathode, the separation of an ion of each kind at the two electrodes respectively is associated with the simultaneous interchange of partners throughout the whole length of the chain. This assumption is sufficiently natural, for if the molecule at one end of the chain, at the anode suppose, be the one decomposed by the current, the anion remains at the anode, but the other part of the molecule, the cation, has to appear at the cathode, so far as we know, simultaneously. Now, on the assumption mentioned above, the time required for the transfer will be the same for long chains as for short ones (since every pair of ions into which the molecules are resolved will be under the action of equal separating forces), and is merely the time required for the separated ions to pass over the distance intervening between a single pair of molecules, and may well therefore be too small for measurement.

The interchange of ions between molecules has indeed long been an accepted notion in electrolysis, and requires no defence. And from the fact that the smallest electromotive force produces a current through an electrolyte, and that the physical properties of the liquid are, so far as we know, identical in every respect, when conducting the current and when not, it also seems natural to suppose that the interchange of ions between the molecules of an electrolyte is constantly going on whether a current is flowing or not, but that the direction of the interchange is fortuitous. The idea of the dissociation and reformation of molecules constituting a dynamical equilibrium of a chemical compound was originally suggested by Williamson[1] to account for etherification, and the explanation of electrolytic action by the same idea is due to Clausius,[2] who suggested that the effect of electromotive force was to determine the direction of the average motion of the respective ions, and not itself to produce the dissociation and recombination.

It would follow that the work required to produce electrolytic decomposition is wholly spent in setting free the ions at the electrodes.

Whatever representation may be made of the state of the molecules of an electrolyte when no current is passing, it must be so arranged as to take account of the fact that when a current passes the dissociation and recombination are attended with the development of a quantity of heat in accordance with Joule's law; whereas when no current passes no heat is developed; and the mere irregularity of direction of motion would not dispose of the heat production because that is independent of the direction of current and depends merely on the magnitude. Professor Fitzgerald

[1] Liebig's *Annalen d. Chem. u. Pharm.* vol. 1, p. 37, 1851.
[2] Pogg. *Ann.* 101, p. 338, 1857.

has remarked that the motion under an E.M.F. is constrained, whereas the motion without E.M.F. is free; and the difference of the two cases with respect to the energy required is thus explained.

Many of the observed phenomena of electrolysis are most easily explained on the assumption of a permanent dissociation of at least a portion of the electrolyte into component parts which become 'ions' (*i.e.* move with the positive and negative electricity respectively) when an electromotive force acts upon the electrolyte. If we may picture to ourselves the whole number of molecules taking part in dissociation and frictionless recombination, being combined molecules for a certain fraction of every instant and dissociated 'ions'[1] for the remainder, the average result for the whole electrolyte will be the same as if the same fraction of the whole number of molecules were permanently combined, the remainder being permanently dissociated. There does not seem to be any experimental method of distinguishing between these two alternatives, and in default of experimental evidence for the one or other we may provisionally adopt whichever we please. But it may be well to accentuate here what Arrhenius ('Zeitschr. f. phys. Chemie,' i. p. 638) has already mentioned, namely, that the term 'dissociation,' as here used, is liable to be misunderstood and confounded with the same term as applied, for instance, to the resolution of an ammonium salt into two separate bodies at a high temperature. As referring to electrolysis, dissociation means the separation of a molecule into atoms or their equivalents, and would only correspond to ordinary dissociation if atoms of the same kind were collected and set free from the liquid. Thus one need not expect a solution of KCl, even though all the salt were dissociated into K and Cl atoms, to smell of chlorine until one has done the work necessary to accumulate the electrified chlorine atoms and produce molecular chlorine; in other words, until the solution has been electrolysed. Free chlorine and dissociated chlorine ions are not by any means to be regarded as identical in physical state. In the electrolytic sense the conception of dissociation is new to science, and the numerical results obtained from its use are the more startling, as those compounds which we have been accustomed to regard as most capable of resisting dissociation in the ordinary sense are precisely those which are electrolytically most completely dissociated.[2]

Quite recently the dissociation theory has been put in such a form as renders it possible to express numerically the fraction of the whole number of molecules which are dissociated in the formation of an electrolyte by solution of a salt in water. The first development of the theory is mainly due to Arrhenius. In Part II. of a memoir[3] presented to the Academy of Sciences of Sweden, June 6, 1883, on the 'Chemical Theory of Electrolytes,' he explains the action of a very large number of chemical changes in solutions on the assumption of a coefficient of activity for each acid or base, representing the ratio of the number of active or dissociated molecules to the whole number of molecules of salt in the solution, the action of the solvent being assumed to be merely to dissociate the salt to a greater or less extent. This ratio is taken to be identical

[1] Mr. J. Brown takes exception to the use of the word in this sense. It avoids circumlocution, however, and stands for 'those parts of a molecule which would become ions if an E.M.F. acted.' A new name might be found for them if necessary.

[2] See Armstrong, *Electrician*, Aug. 26, 1887, and on the other side Ostwald, *Zeitschr. für phys. Chem.* ii. p. 270 (1888).

[3] See *B.A. Report*, 1886, p. 357.

with, or numerically expressed by, the ratio of the molecular conductivity of the solution to the molecular conductivity of an infinitely dilute solution of the same compound, in which all molecules are probably dissociated. The explanation of chemical phenomena thus given is sufficiently well established to indicate some relation, at any rate, between conductivity and chemical activity, but a more direct comparison may be made between conductivity and dissociation as measured indirectly on the basis of Van 't Hoff's theory of the effects of osmotic pressure.[1] On Van 't Hoff's theory the osmotic pressure of a salt in solution at a given temperature depends upon the number of molecules contained in a given volume irrespective of the weight of the individual molecules; so that if the osmotic pressure be regarded as corresponding to gaseous pressure, Avogadro's law holds for salts in solution as well as gases. Van 't Hoff verified this law for a number of bodies, leaving, however, a number of exceptions, and Arrhenius has shown that the exceptions may in general be quite satisfactorily explained by supposing that the effective number of the molecules is increased by the dissociation of some into ions, and the fraction of the whole number that must be supposed dissociated in order to account for the exceptional osmotic pressure is, within very small limits of difference, the same as the dissociation ratio—that is, the fraction of the whole number required to be dissociated in order to account for the conductivity on the dissociation hypothesis; or, to express the fraction free from hypothesis, it is the fraction represented by the ratio of the molecular conductivity of a given salt-solution to the limiting value of the molecular conductivity of the salt when the dilution is indefinitely great. Let α represent this 'dissociation ratio,' or coefficient of activity, as it is termed by Arrhenius, which can be determined from measurements of conductivity at different degrees of dilution.[2] Let m be the number of inactive, or undissociated, molecules in unit volume of solution, n the number of active molecules, each of which we may suppose dissociated into k ions (*e.g.*, for KCl, $k=2$; for $BaCl_2$, or K_2SO_4, $k=3$, and so on); then, assuming that each separate ion is as effective as regards osmotic pressure as each combined molecule, the osmotic pressure will be the same as if the whole number of molecules were $m+kn$; the ratio i of this number to the whole number of original molecules is $(m+kn)/(m+n)$, whereas $\alpha=n/(m+n)$. Whence $i=1+(k-1)\alpha$. On the other hand, the osmotic pressure, and consequently the number of effective molecules in unit volume, can be determined on Van 't Hoff's theory by observing the depressions of the freezing-point of water, as Raoult has done in many cases, produced by the solution of one gramme-molecule of salt in a litre. Thus the normal[3] depression of the freezing-point for one gramme-molecule of salt when there is no dissociation is 1·85° C., so that if t be an observed depression of the freezing-point for a gramme-molecule of

[1] Van 't Hoff, *Zeitschr. für ph. Ch.* i. p. 481, 1887. 'Trans.' by Ramsay, in *Phil. Mag.* ser. 5, 26, p. 81, 1888. Arrhenius, *Zeitschr. für ph. Ch.* i. p. 631, 1887. *B.A. Rep.* 1887.

[2] The molecular conductivity for infinite dilution may be arrived at by plotting a curve with the number of gramme-molecules per litre of solutions of different concentration as abscissæ and the molecular conductivities (*i.e.* conductivity ÷ number of gramme-molecules per litre) as ordinates, and continuing the curve until it meets the line of no concentration. (See Kohlrausch, Wied. *Ann.* vol. 26.)

[3] For an account of the application of the depression of the freezing-point to the examination of the molecular constitution of dilute solutions, see also Planck, *Zeitschr. für phys. Chem.* i. p. 577 (1887); Wied. *Ann.* vol. 32, p. 499.

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electrolyte, $t/1·85$ is the ratio of the number of molecules in unit volume of electrolyte to what would be the number in unit volume if there were no dissociation. Hence $i = t/1·85$.

These molecular depressions of the freezing-point have been determined by Raoult by observing the effect of the dissolution of one gramme of the salt in one litre of water. Hence, if the conductivity of the solution of the same strength be known, we have two independent methods of determining i, one of which comes from conductivity measurements and the other from thermal measurements, based on the assumption of dissociation. The results are given in a table ('Zeitschr.' vol. 1, p. 634). The numbers in the column based on conductivities are calculated from Ostwald for acids and bases, from Kohlrausch for most salts, but some also from Long, Grotrian, Klein, and Ostwald. For the better conducting salts the figures may be 10 or 15 per cent. in error, interpolation and extrapolation having to be used. For worse conducting salts the possible error is smaller, and for acids and bases at the most 5 per cent. 'Of the accuracy of Raoult's numbers I am not sure; an error of 5 or 10 per cent. seems likely.'[1] The conductivity was measured at 18° C., or 25° C., and the lowering of the freezing-point at about 0° C. Considering all this, the numbers seem fairly accordant with certain exceptions,[2] of

[1] Arrhenius, 'B.A. Electrolysis Committee Sixth Circular,' *Zeitschr.* 1, p. 636.

[2] In a subsequent communication to *Zeitschr. f. ph. Chem.* ii. p. 491, Arrhenius returns to the consideration of the comparison of the numbers and determines the freezing-point depressions, and so redetermines the values of i. The results are contained in the following table:—

TABLE V.—*Table of Comparisons of observed and calculated Values of Freezing-point Depression in Aqueous Solutions.*

(From Arrhenius, 'Zeitschr. für ph. Chem.' vol. 2.)

Substance Dissolved	Grammes of Substance per 100 cc.	Gramme-molecules per Litre g	Depression of Freezing-point d	Molecular Depression $\delta = d/g$	i Observed $= \frac{\delta}{1·89}$	i' Calculated from Conductivities $1+(k-1)\alpha$	$i' : i$	Coefficient of Dissociation $\alpha = \frac{i'-1}{k-1}$
A.—NON-CONDUCTORS								
1. Methylalcohol. CH_3OH	0·319	0·100	0·184	1·84	0·97		Identical with column headed 'i Observed.'	
	0·638	0·200	0·356	1·78	0·94			
	1·51	0·485	0·886	1·82	0·96			
	3·00	0·97	1·831	1·89	1·00			
2. Ethylalcohol C_2H_5OH	0·575	0·125	0·229	1·83	0·97			
	1·44	0·313	0·591	1·89	1·00			
	2·85	0·62	1·183	1·91	1·01			
	5·70	1·24	2·456	1·98	1·05			
3. Propylalcohol C_3H_7OH	0·61	0·102	0·196	1·93	1·02			
	1·53	0·255	0·479	1·88	1·00	1		
	3·83	0·638	1·202	1·89	1·00			
	6·37	1·06	2·065	1·95	1·03			
4. Isopropylalcohol C_3H_7OH	0·61	0·102	0·193	1·90	1·00			
	1·52	0·253	0·476	1·88	1·00			
	3·79	0·631	1·212	1·92	1·01			
	6·32	1·053	2·095	1·99	1·05			
5. Isobutylalcohol C_4H_9OH	0·91	0·123	0·249	2·02	1·07			
	2·28	0·308	0·591	1·92	1·02			
	5·71	0·771	1·484	1·92	1·02			
	9·52	1·29	2·60	2·02	1·07			

which two are from older observations by Rüdorff. The behaviour of one of the exceptions—H_2SiF_6—is explicable by its partial dissocia-

TABLE OF COMPARISONS—*continued.*

Substance Dissolved	Grammes of Substance per 100 cc.	Gramme-molecules per Litre g	Depression of Freezing-point d	Molecular Depression $\delta = d/g$	i Observed $= \frac{\delta}{1 \cdot 89}$	i' Calculated from Conductivities $1+(k-1)\alpha$	$\frac{i}{i'}$	Coefficient of Dissociation $\alpha = \frac{i'-1}{k-1}$
NON-CONDUCTORS—*cont.*								
6. Ethylether $(C_2H_5)_2O$	0·87	0·118	0·22	1·87	0·99			
	1·74	0·235	0·42	1·79	0·95			
	2·87	0·388	0·73	1·88	1·00			
	5·74	0·776	1·51	1·95	1·03			
7. Phenol C_6H_5OH	0·952	0·101	0·183	1·81	0·96			
	2·029	0·216	0·392	1·82	0·96			
	3·381	0·36	0·639	1·78	0·94			
	5·244	0·558	0·967	1·75	0·93			
8. Aniline $C_6H_5NH_2$	1·016	0·109	0·210	1·92	1·02			
	2·54	0·273	0·499	1·83	·97			
9. Boracic acid $B(OH)_3$	0·41	0·066	0·129	1·95	1·03			
	1·024	0·165	0·318	1·93	1·02			
	1·706	0·274	0·532	1·93	1·02			
10. Acetamide CH_3CONH_2	0·702	0·119	0·233	1·96	1·04			
	1·756	0·297	0·568	1·91	1·01			
	4·39	0·744	1·423	1·91	1·01			
	7·32	1·240	2·422	1·95	1·03			
11. $CO(NH_2)_2$	0·622	0·104	0·209	2·02	1·07			
	1·555	0·259	0·493	1·90	1·01			
	3·887	0·648	1·219	1·88	0·99			
	6·478	1·080	2·018	1·87	0·99			
12. Chloral hydrate $C_2Cl_3H(OH)_2$	1·759	0·106	0·218	2·05	1·08			
	4·397	0·266	0·525	1·98	1·05			
	10·99	0·664	1·355	2·04	1·08	1	Identical with column headed 'i Observed.'	
	18·32	1·107	2·378	2·15	1·13			
13. Bromal hydrate $C_2Br_3H(OH)_2$	2·14	0·0716	0·137	1·91	1·01			
	5·34	0·179	0·335	1·87	0·99			
	13·36	0·447	0·829	1·86	0·98			
	22·26	0·745	1·377	1·85	0·98			
14. Glycerine $C_3H_5(OH)_3$	1·346	0·146	0·287	1·96	1·04			
	2·34	0·254	0·492	1·93	1·02			
	4·80	0·522	1·061	2·03	1·07			
	7·603	0·826	1·725	2·09	1·11			
	11·16	1·213	2·612	2·15	1·14			
15. Mannite $C_6H_{14}O_6$	2·93	0·161	0·333	2·07	1·09			
	7·33	0·403	0·835	2·07	1·10			
	12·21	0·671	1·420	2·12	1·12			
16. Dextrose $C_6H_{12}O_6$	1·211	0·0673	0·132	1·96	1·04			
	3·028	0·168	0·340	2·02	1·07			
	7·57	0·421	0·845	2·01	1·06			
	12·62	0·701	1·460	2·08	1·10			
17. Cane sugar $C_{12}H_{22}O_{11}$	1·523	0·0445	0·091	2·04	1·08			
	3·246	0·0947	0·200	2·11	1·11			
	5·629	0·165	0·337	2·05	1·08			
	10·797	0·316	0·670	2·12	1·12			
	16·88	0·494	1·113	2·25	1·19			
	27·65	0·809	2·057	2·54	1·34			
	34·56	1·010	2·74	2·71	1·43			

tion into SiO_2 and 6HF.[1] The results are somewhat startling. That, when dissolved in a hundred times its weight of water, KHO should be

TABLE OF COMPARISONS—*continued.*

Substance Dissolved	Grammes of Substance per 100 cc.	Gramme-molecules per Litre g	Depression of Freezing-point d	Molecular Depression $\delta = d/g$	i Observed $= \frac{\delta}{1{\cdot}89}$	i' Calculated from Conductivities $1+(k-1)a$	$\frac{i}{i'}$	Coefficient of Dissociation $a = \frac{i'-1}{k-1}$
B.—ELECTROLYTES.								
18. Lithium hydrate LiOH	0·304	0·127	0·474	3·74	1·98	1·90	1·04	·90
	0·760	0·317	1·131	3·57	1·89	1·86	1·02	·86
19. Acetic acid CH_3COOH	0·81	0·135	0·268	1·98	1·05	1·01	1·04	·01
	2·02	0·337	0·655	1·96	1·04	1·01	1·03	·01
	5·05	0·842	1·61	1·91	1·01	1·00	1·01	·00
	8·42	1·403	2·68	1·91	1·01	1·00	1·01	00
20. Butyric acid C_3H_7COOH	1·23	0·140	0·276	1·97	1·04	1·01	1·03	·01
	3·07	0·349	0·660	1·89	1·00	1·01	0·99	·01
	7·67	0·872	1·589	1·82	0·96	1·00	0·96	·00
21. Phosphoric acid H_3PO_4	0·755	0·077	0·201	2·61	1·38	1·32	1·05	·11
	1·430	0·146	0·350	2·40	1·27	1·25	1·01	·08
	3·125	0·319	0·734	2·30	1·22	1·20	1·01	·07
22. Sulphurous acid H_2SO_3	0·747	0·091	0·259	2·85	1·51	1·34	1·12	·16
	1·31	0·159	0·410	2·58	1·36	1·25	1·09	·12
	2·28	0·279	0·690	2·47	1·31	1·22	1·07	·11
	3·82	0·466	1·16	2·49	1·32	—	—	—
	6·73	0·820	2·01	2·45	1·30	—	—	—
23. Iodic acid HIO_3	2·009	0·114	0·35	3·05	1·61	1·70	0·95	·70
	4·007	0·228	0·69	3·02	1·60	1·61	0·99	·61
	5·01	0·285	0·85	2·97	1·57	1·58	0·99	·58
24. Phosphorous acid $P(OH)_3$	0·611	0·074	0·227	3·07	1·62	1·59	1·02	·20
	1·018	0·124	0·342	2·76	1·46	1·51	0·97	·17
	2·036	0·248	0·654	2·64	1·36	1·43	0·95	·14
25. Oxalic acid $(COOH)_2+2H_2O$	0·867	0·0688	0·211	3·07	1·62	1·55	1·05	·27
	1·651	0·131	0·375	2·86	1·51	1·47	1·03	·23
	3·106	0·247	0·650	2·64	1·40	1·38	1·01	·19
26. Sodium chloride NaCl	0·273	0·0467	0·117	3·07	2·00	1·88	1·07	·88
	0·682	0·117	0·424	3·64	1·93	1·84	1·05	·84
	1·136	0·194	0·687	3·54	1·87	1·82	1·03	·82
	1·893	0·324	1·135	3·51	1·86	1·79	1·04	·79
	3·155	0·539	1·894	3·50	1·85	1·74	1·06	·74
27. Lithium chloride LiCl	0·419	0·099	0·363	3·67	1·94	1·80	1·08	·80
	0·698	0·165	0·606	3·67	1·94	1·78	1·09	·78
	1·167	0·275	1·019	3·71	1·95	1·75	1·12	·75
	1·945	0·458	1·729	3·78	2·00	1·70	1·18	·70
28. Silver nitrate $AgNO_3$	0·952	0·056	0·214	3·82	2·02	1·86	1·09	·86
	2·381	0·140	0·501	3·58	1·90	1·81	1·05	·81
	5·932	0·341	1·143	3·35	1·77	1·73	1·02	·73
29. Potassium sulphate K_2SO_4	0·633	0·0364	0·184	5·06	2·68	2·45	1·09	·72
	1·583	0·091	0·405	4·45	2·35	2·33	1·01	·66
	3·957	0·227	0·95	4·18	2·21	2·18	1·01	·59
	7·914	0·455	1·755	3·86	2·04	2·06	0·99	·53
30. Sodium sulphate $Na_2SO_4+10H_2O$	0·903	0·0280	0·141	5·03	2·66	2·47	1·07	·73
	2·258	0·0701	0·326	4·65	2·46	2·33	1·06	·66
	3·763	0·117	0·515	4·41	2·33	2·29	1·02	·63
	6·21	0·195	0·817	4·19	2·21	2·17	1·02	·58

[1] For suggestions in explanation of some of the exceptions, see *Zeitschr. für ph. Chem.* i. p. 639.

dissociated to the extent of 90 per cent., BaH_2O_2 94 per cent., HCl 90 per cent., KCl 86 per cent., while the dissociation of $MgSO_4$ reaches only 40

TABLE OF COMPARISONS—*continued.*

Substance Dissolved	Grammes of Substance per 100 cc.	Gramme-molecules per Litre g	Depression of Freezing-point d	Molecular Depression $\delta = d/g$	i Observed $= \frac{\delta}{1{\cdot}89}$	i' Calculated from Conductivities $1+(k-1)\alpha$	$\frac{i}{i'}$	Coefficient of Dissociation $\alpha = \frac{i'-1}{k-1}$
ELECTROLYTES—*cont.*								
31. Calcium chloride $CaCl_2$	0·530	0·0476	0·248	5·17	2·74	2·52	1·09	·76
	1·224	0·119	0·594	4·95	2·62	2·42	1·09	·71
	2·206	0·199	0·993	5·01	2·66	2·34	1·13	·67
	3·677	0·331	1·706	5·16	2·73	2·24	1·22	·62
32. Strontium chloride $SrCl_2$	0·664	0·043	0·231	5·37	2·84	2·54	1·12	·77
	1·686	0·107	0·523	4·89	2·59	2·45	1·06	·72
	3·372	0·214	1·053	4·92	2·60	2·32	1·12	·66
	5·62	0·356	1·791	5·03	2·66	2·22	1·20	·61
33. Calcium nitrate $Ca(NO_3)_2$	1·055	0·0643	0·304	4·72	2·50	2·35	1·06	·67
	1·759	0·1073	0·496	4·62	2·45	2·23	1·10	·61
	2·931	0·179	0·819	4·58	2·42	2·08	1·16	·54
34. Magnesium chloride $MgCl_2$	0·49	0·0532	0·223	5·13	2·71	2·43	1·12	·71
	1·224	0·133	0·667	5·02	2·66	2·38	1·12	·69
	3·06	0·322	1·716	5·33	2·82	2·19	1·29	·59
	5·10	0·537	3·06	5·70	3·02	2·09	1·44	·54
35. Cupric chloride $CuCl_2+2H_2O$	0·641	0·0377	0·193	5·12	2·71	2·53	1·07	·76
	1·603	0·094	0·455	4·83	2·56	2·41	1·06	·70
	4·008	0·235	1·127	4·79	2·53	2·19	1·16	·59
	6·68	0·393	1·917	4·86	2·57	2·04	1·26	·52
36. Cadmium iodide CdI_2	1·991	0·0544	0·161	2·96	1·57	1·53	1·02	·26
	4·978	0·136	0·320	2·35	1·24	1·39	0·90	·19
	12·517	0·342	0·715	2·09	1·11	1·31	0·84	·15
	25·03	0·684	1·523	2·19	1·16	1·25	0·91	·12
37. Magnesium sulphate $MgSO_4+7H_2O$	1·566	0·0638	0·164	2·59	1·37	1·44	0·95	·44
	3·915	0·159	0·366	2·30	1·22	1·38	0·88	·38
	9·787	0·398	0·802	2·02	1·07	1·28	0·83	·28
	16·311	0·663	1·303	1·97	1·04	1·24	0·85	·24
38. Zinc sulphate $ZnSO_4+7H_2O$	1·976	0·0689	0·169	2·45	1·30	1·39	0·93	·39
	4·941	0·172	0·367	2·13	1·13	1·35	0·83	·35
	12·35	0·430	0·799	1·86	0·98	1·25	0·78	·25
	20·59	0·718	1·296	1·81	0·96	1·22	0·78	·22
39. Copper sulphate $CuSO_4+5H_2O$	0·979	0·0393	0·099	2·52	1·33	1·41	0·95	·41
	2·80	0·112	0·244	2·17	1·15	1·34	0·85	·34
	6·326	0·254	0·493	1·94	1·03	1·27	0·81	·27
	13·04	0·523	0·926	1·77	0·94	1·22	0·77	·22
	24·25	0·973	1·687	1·73	0·92	1·18	0·78	·18
40. Cadmium sulphate $CdSO_4+8/3H_2O$	1·067	0·0417	0·108	2·59	1·37	1·39	0·99	·39
	2·667	0·104	0·237	2·28	1·21	1·31	0·92	·31
	5·006	0·196	0·420	2·15	1·14	1·27	0·90	·27
	12·52	0·489	0·938	1·92	1·02	1·21	0·84	·21
	20·86	0·815	1·535	1·88	0·99	1·19	0·84	·19
	34·77	1·36	2·68	1·97	1·04	1·13	0·92	·13

For the discussion of those cases in which the ratio i/i' differs from unity, see *Zeitschr. für ph. Chem.* ii. p. 497, 1888. The measurements for LiCl, KCl, NH_4Cl, $CaCl_2$, $SrCl_2$, $MgCl_2$, $CuCl_2$, $MgSO_4$, $Ca(NO_3)_2$, $FeCy_6K_4$ have been repeated, and the results confirmed by Van 't Hoff and Reicher (*Zeitschr. für ph. Chem.* iii. p. 198). $MgSO_4$ and the chlorides remain intractable, possibly in the former case on account of the for-per cent., and that of acetic acid only 1 per cent., $HgCl_2$ only 3 per cent., is not what one would expect *à priori*; but the general agreement of the results is so close that it can hardly be explained away. The theory is further supported in Arrhenius's original paper by the consideration of a number of properties which are additive in dilute solutions; that is to say, the numerical values of these properties can be regarded as the sums of the values corresponding to separate parts, namely, the solvent, and the component ions into which the molecules of the salt are separated. A well-known example is that of electric conductivity,[1] which, for a very dilute solution, can be numerically regarded as made up of numbers corresponding respectively to the solvent and the several ions.

The other properties of dilute solutions which Arrhenius mentions in this connection are the heats of neutralisation,[2] specific gravity and specific volume,[3] specific refractive power,[3] depression of the freezing-point[4] and other properties connected with it, diminution of vapour pressure, osmotic pressure, and isotonic coefficient.[5] These additive properties have of themselves suggested the more or less complete dissociation of salts.[6] Perhaps the most striking corroboration of Arrhenius's theory is that the cases in which the additive law is not satisfactorily made out, are precisely the cases in which the dissociation ratios deduced from the resistance measurements are considerably less than unity, even in dilute solutions.

Against this formidable array of reasons in favour of the dissociation hypothesis, Armstrong[7] has urged a number of considerations, among which are the following: There are difficulties from the chemist's point of view, which dispose him to reject the idea that electrolysis is primarily an affair of atoms; 'peculiarities and relationships which are patent to the chemist,' but which 'it is impossible at present to quantify.' Moreover, it seems to be difficult to accept the idea that an electrolyte can be decomposed by an infinitesimal electromotive force unless further proof is forthcoming;[8] and, again, there are anomalies that the dissociation theory does not explain, as, for instance, the conductivity of fused silver iodide in face of the non-conductivity of water and of pure hydrochloric acid, the dissociation of hydrochloric acid by water without a corresponding dissociation of the water, and the more complete dissociation of what have always been regarded as the more stable compounds. The parallelism of diffu-

mation of double molecules, even in dilute solutions, and in the case of $CaCl_2$ on account of the formation of CaCl (Van 't Hoff and Reicher).

Those cases in which the ratio $\frac{i'}{i}$ is considerably less than 1 in strong solution can be explained by ascertaining the formation of double molecules in the stronger solutions.

[1] Kohlrausch, Wied. *Ann.* 6, p. 167 (1879); 26, pp. 215, 216 (1885); Ostwald, *Zeitschr. für ph. Chem.* 1, pp. 74 and 97 (1887).

[2] Ostwald, *Lehrbuch der allgemeinen Chemie*, p. 1250; Arrhenius, *l.c.* p. 643.

[3] Valson, *C.R.* 73, p. 441 (1871); Ostwald, *Lehrbuch*, i. p. 384.

[4] Raoult, *Ann. d. Ch. et d. Phys.* [6] 4, p. 401 (1885).

[5] De Vries, *Pringsheim's Jahrbücher für wiss. Bot.* 14, p. 519 (1883).

[6] Valson, *C.R.* 73, p. 441 (1871); 74, p. 103 (1872), 75, p. 1330 (1872); Raoult, *Ann. de Chim.* [6] 4, 401, 426.

[7] *Proc. Roy. Soc.* 1886, p. 268; *Electrician*, Aug. 26, 1887.

[8] See a paper by Ostwald and Nernst, *Zeitschr. für ph. Chem.* 3, p. 120, 1889, 'On Free Ions,' in which it is shown, on the assumption that the energy developed by the discharge of a conductor in a liquid is proportional to the square of the loss of electricity, that no work is done by the electromotive force in separating the molecules into ions.

sive power and conductivity is said to be almost conclusive evidence against the theory. Armstrong suggests instead a theory of electrolysis based upon the formation and decomposition of molecular aggregates under the influence of residual affinity, and he has in his favour, so far as it goes, the evidence given on p. 204 for the existence of definite hydrates in solution. But, as he himself says, his objections to the dissociation theory cannot be regarded as definite experimental reasons which make the theory untenable, but rather as suggesting knotty points which those in favour of the theory have to deal with. Arrhenius has replied to the objections,[1] and has to a certain extent met that based on the constants of diffusion; the others can only be definitely decided upon by the subsequent development of the theory.[2]

Some considerable advance has already been made. Ostwald ('Zeitschr. f. phys. Chem.' vol. 2, p. 270) explains that the theory accounts satisfactorily for the following six relations, which were previously accepted as empirical generalisations of the results of observation:—

1. The molecular conductivity of all electrolytes increases with increasing dilution, and approaches asymptotically a maximum value.

2. These maximum values on the one hand for acids, secondly for bases, and thirdly for salts (referred to equivalent quantities) are of the same order of magnitude, but not strictly equal.

3. The maximum values can be represented as the sum of two magnitudes, of which the one depends only on the positive, the other only on the negative ion (Kohlrausch's law).

4. For electrolytes of higher concentrations as well as for weak acids and bases the previous statement does not hold; an approximation thereto is apparent when one compares groups of salts whose ions are of equal valency.

5. Electrolytes of low conductivity, such as weak acids and bases, have their molecular conductivity very rapidly increased with increasing dilution. With monobasic acids and normal bases the conductivity increases in proportion to the square root of the volume of solvent.

6. The increase of molecular conductivity takes place with all monobasic acids and monovalent bases, according to the same law. If one compares such electrolytes, for dilutions at which these conductivities are equal fractions of the maximum, the degrees of dilution (or volumes corresponding to one gramme-molecule) are in constant ratio.

In order to prove these statements from the dissociation theory, Ostwald pushes the analogy between the state of the molecules in a solution and the state of gaseous molecules a step further. Adopting, from the theory of dissociation of gases (Ostwald's 'Lehrbuch,' 2, p. 723), the formula $R \log \frac{p}{p_1 p_2} = \frac{\rho}{T} + \text{const.}$, where p is the pressure of the undissociated part, p_1 and p_2 the partial pressures of the dissociated constituents, and assuming the temperature to be constant and the two sets of ions to be equally numerous, he obtains an equation $p/p_1^2 = c$, which, on the assumption of identity or strict analogy of molecular constitution in solutions, applies to the dissociation of a salt in a solvent. Transforming this equation in terms of molecular conductivities, on the assumption that these depend

[1] *Electrician*, Sept. 7, 1888.

[2] The theory is also criticised by E. Wiedemann, *Zeitschr. für ph. Chem.* vol. 2, p. 241, 1888.

on the number of molecules dissociated, and that the dissociation is complete in infinite dilution, we get (p. 277)

$$\frac{\mu_\infty(\mu_\infty - \mu_v)}{\mu_v^2}v = c',$$

where μ_∞ is the limiting maximum of molecular conductivity, μ_v the molecular conductivity at volume v per gramme-molecule, and c' is constant at constant temperature.

From this formula the above six statements may be immediately deduced. It also furnishes a new basis of comparison; for writing m for μ_v/μ_∞ we get the following new relation between molecular conductivities at different dilutions:

$$\frac{m^2}{(1-m)v} = k.$$

Ostwald gives a number of values of the constant k for acetic acid, angelica acid, α-chlorisocrotonic acid, o-oxysalicylic acid, and the numbers agree quite satisfactorily; according to Ostwald, more nearly than the corresponding numbers for the formula as applied to gaseous dissociation.[1]

We give one table referring to butyric acid:

v	μ	k	C′ (corrected for high pressures and changes of viscosity)
2	1·726	0·1152	0·1538
4	2·648	0·1359	0·1554
8	3·870	0·1475	0·1549
16	5·554	0·1509	0·1557
32	7·874	0·1530	0·1551
64	11·16	0·1545	0·1560
128	15·67	0·1541	0·1550
256	22·67	0·1560	0·1560
512	30·73	0·1558	0·1558
1,024	42·40	0·1535	0·1535

The column headed k should give the same values throughout; the earlier values are evidently too small, but the differences are accounted for on the hypotheses (1) that at high concentrations the osmotic pressure is very high, viz. 24 atmospheres in a normal solution (1 gm.-molecule in 1 litre); at these high pressures the gaseous laws do not hold, and a correction term must be introduced, as in the case of gases by Van der Waals, which alters the formula to the form $\frac{m^2}{1-m} = C(v-b)$. (2) The conductivity depends not only on the dissociation but also on the fluidity of the solution; hence, in order to compare the conductivities for the purpose of this formula, which takes account of the dissociation alone, the observed conductivity must be reduced to a theoretical conductivity

[1] In three papers in vol. iii. of the *Zeitschr. für ph. Chem.* pp. 170, 241, 369, Ostwald has determined the value of the constant k in the above formula for a large number of organic acids. The values tabulated are those of $K = 100k$ (p. 174). An index of the acids thus investigated is given *l.c.*, p. 418. The physical meaning of the constant is that at concentration $2k$ half of the acid is dissociated.

in a liquid of normal fluidity by multiplying by the coefficient of viscosity referred to pure water. The numbers as corrected in the way thus indicated are given in the fourth column headed C′ (v being taken at ·1 litre). The improvement of the agreement throughout the range of numbers is sufficiently apparent.

The application of Ostwald's formula is confirmed by observations of Van 't Hoff and Reicher.[1]

Arrhenius has further applied the dissociation hypothesis to account for the observed results obtained for the conductivity of mixtures, and has also recast his theory of chemistry to comply with the more recent development of the dissociation theory without interfering with its appositeness to the explanation of chemical observations, and he has deduced the effect of neutral salts upon the reaction velocities of weak bases and acids in saponification, and compared the results with observation, and found a satisfactory agreement.

De Vries, in a paper on osmotic experiments with living membranes,[2] has compared the values of isotonic coefficients[3] as calculated from the molecular conductivities and observed with membranes, and found a satisfactory agreement.[4]

In an interesting paper[5] on the effect of the dissociation theory upon the general ideas of chemistry, Ostwald explains the thermal effects of reactions in dilute solutions. If, for instance, solutions of KHO and HCl are mixed, a quantity of heat, 137K,[6] is produced, and this heat has hitherto been regarded as the heat of formation of KCl. But on the dissociation theory the KCl remains dissociated in the solution to the extent, at any rate, of 90 per cent. At the same time an equivalent of water is formed by the union of the H of the HCl and the HO of the KHO; the heat set free by this may be taken to be 135K, and it constitutes nearly the whole amount of the heat developed. On this view, for all those reactions in which an easily dissociated salt is formed, together with a molecule of water, the heat of formation will be that of the molecule of water merely, and will not depend on the other reacting bodies. This is amply borne out by the data supplied by Thomsen for the heat of neutralisation of a number of acids by soda solution. When two molecules of water are formed (with dibasic acids) the heat of neutralisation is doubled. The differences are accounted for by the incompleteness of the dissociation of the acid and bases, so that the heat of neutralisation of an equivalent of acid may in general be represented by a formula $Q=135+a+b$.

The theory is also extended to the explanation of the thermo-neutrality of solutions—that is, to the absence of heating effect when neutral salts are mixed, and the exceptional cases—*e.g.* the chloride of mercury—are those cases in which the dissociation of the salts is not nearly complete.

It is interesting to note how far the dissociation is supposed to be carried. For Arrhenius's table, an electrolytic molecule may be resolved

[1] *Zeitschr. für ph. Chem.* 2, p. 777, 1888. [2] *Ibid.* p. 415, 1888.

[3] Solutions which have equal osmotic pressure are called isotonic, and the corresponding concentrations isotonic concentrations. The reciprocal of the isotonic concentration in molecular quantities is called the 'isotonic coefficient,' which is therefore the number of litres per gramme-molecule required to give a certain osmotic pressure.

[4] *L.c.* p. 430. [5] *Zeitschr. für ph. Chem.* 3, p. 588, 1889.

[6] K represents 100 gramme Centigrade thermal units.

into a number of ions, thus into two in the case of KCl, into three in the cases $BaCl_2$ and K_2SO_4; the dissociation detaches but preserves intact a multivalent complex ion from a number of monovalent ones, and also separates the monovalent ones one from another. Ostwald, in his formula, refers only to binary compounds, each molecule of which is resolved into two ions; but in considering the application of the dissociation hypothesis to chemistry in the paper already referred to,[1] he touches upon an interesting point. He lays down the principle that chemical reactions consist in the exchange of ions, and therefore take place exclusively between ions. Thus a number of chlorine compounds give no reaction with silver because the chlorine does not appear as an ion. This principle enables one to distinguish between salts of composite acids (as, for instance, Na_2PtCl_6 and $K_4Fe(CN)_6$, which show such reactions as are compatible with splitting up into ions Na and $PtCl_6$ and K and $Fe(CN)_6$ respectively) and true double salts, as the alums, which in solution are resolved, and do not exist as double salts.

These hypotheses can be verified by the depression of the freezing-point in the solutions, for the number of the ions is different in the two cases. Thus the double salt $3K_2C_2O_4+Cr_2(C_2O_4)_3$ would form fourteen ions, whereas if it were really $2K_3,CrC_6O_{12}$ only eight ions would be formed from the same molecule.

But perhaps the most interesting, as being the least evident suggestion, is that which, based on reactions similar to the slow precipitation of silver chloride with separation of glycolic acid from monochlor-acetate solution, is thus expressed (p. 598): 'In order to express this consideration in general terms we must say that an electrolyte may ultimately split up in different directions. Usually one definite direction is far away the most prominent, and the corresponding reactions are completed in immeasurably short time; to the other directions correspond processes which proceed slowly. Since the organic compounds in particular, in so far as they are not salts, belong entirely to the class of non-electrolytes in the ordinary sense, and are therefore not split into ions to an appreciable extent, we obtain on these grounds an explanation of the slowness of the march of the processes so characteristic of this department. It is very probable that the effect of the accelerators, of the hydrogen-chloride in the formation of ethers, the ferric chloride in chlorination, the acetic ether in the action of sodium, and so on, consists in nothing else than the formation of composite electrolytes.'

In the July number of the 'Zeitschrift für physikalische Chemie,' 1889 (p. 96), Arrhenius has given some interesting developments of the dissociation theory. He first of all gives the molecular conductivities of a number of salts at 18° C. and 52° C. and the temperature coefficients deduced therefrom, for a number of solutions of different concentration, having in view the effects which may be due to the alteration of the dissociation ratio with temperature. Then taking, as Ostwald had done (p. 217), the equation of gaseous dissociation $\frac{p_1p_2}{P}=kT$ and also the equation

$$\frac{d \cdot \log_e \frac{p_1p_2}{P}}{dt}=\frac{A}{R}\frac{W}{T^2}$$

[1] *Zeitschr.* 3, p. 596.

deduced from the dynamical theory of heat as applicable to the osmotic phenomena of solutions, where T is the absolute temperature, P is the partial pressure of the combined molecules, $p_1 p_2$ the partial pressures of the dissociated ions, A the dynamical equivalent of heat, W the heat of formation of the molecules from the ions, he obtains the equation

$$2{\cdot}35\,\frac{d\log_{10}k}{dt}+\frac{1}{T}=\frac{A}{R}\frac{W}{T^2}.$$

Whence, substituting values of A and R in meter-gramme units (424·4/0·981 and 845·05 respectively), we get

$$W=1{\cdot}945\times2{\cdot}35\,T^2\,\frac{d\log_{10}k}{dt}+1{\cdot}945\,T,$$

where W is expressed in gramme-calories; k can be determined from the conductivity measurements, and hence $d\log k/dt$ approximately determined which is denoted by β, and hence the value of W determined for the mean temperatures 35° C. (between 18° and 52°) and 21°·5 (between 18° and 25°). The results are as follows:—

A.—*Weak Acids.*

Name	At 35°	At 21·5°	$W_{35}-W_{21\cdot5}$
	W_{35}	$W_{21\cdot5}$	
CH_3COOH	+220	+600	−380
C_2H_5COOH	+50	+390	−340
C_3H_7COOH	−320	+150	−470
$C_2H_4(COOH)_2$ . . .	+1040	+1690	−650
$CHCl_2COOH$	−2240	−2390	+150
H_3PO_4	−1820	−1530	−290
$HOPOH_2$	−3630	−3180	−450
HF(at 33°)	−2960	—	—

B.—*Strongly dissociated Bodies at* 35° (*from Observations in decinormal Solutions*).

Name	W_{35}	Name	W_{35}
KBr	+180	$NaCH_3COO$	+210
KI	−300	NaC_2H_5COO	+690
KCl	+250	NaC_3H_7COO	+1140
KNO_3	+470	$NaHC_2H_4(COO)_2$ . .	+1110
NaCl	+140	$NaCHCl_2COO$ . . .	−190
LiCl	+210	$NaOPOH_2$	+410
$\frac{1}{2}BaCl_2$	+300	NaH_2PO_4	+220
$\frac{1}{2}MgCl_2$	−40	HCl	−460
$\frac{1}{2}CaSO_4$	−940	HNO_3	−740
NaF	+530	HBr	−990
		NaOH	−670

The table shows that heat is sometimes developed and sometimes absorbed by the separation of a molecule into ions.

The values thus obtained are next applied to calculate the heat of neutralisation of the salts investigated. Taking Ostwald's suggestion of the process taking place in neutralisation and setting d_1, d_2, d_3 for the dissociation ratio of the components in the original solutions and the products (exclusive of the water) in the mixture respectively, W_1, W_2, W_3, the heats of dissociation, the amounts of heat necessary to complete the dissociation of each part would be $W_1(1-d_1)$, $W_2(1-d_2)$, and $W_3(1-d_3)$ respectively. Hence, there being no work done, the heat developed in mixing would be

$$N= -(1-d_1)W_1-(1-d_2)W_2+x+(1-d_3)W_3,$$

where x is the heat of formation of the water, deduced from the change of heat of neutralisation of HCl with temperature as 12950 cal.[1]

In this way the following heats of neutralisation of acids were determined and compared with the known values observed experimentally:—

Name	Heat of Neutralisation (with NaOH) at 21°·5		
	Calculated	Observed	Difference
HCl	13700	13740	+40
HBr	13700	13750	−10
HNO_3	13810	13680	−130
CH_3COOH . . .	13070	13400	+330
C_2H_5COOH . . .	13400	13480	+80
C_3H_7COOH . . .	13750	13800	+50
$C_2H_4(COOH)_2$ . . .	12240	12400	+160
$CHCl_2COOH$ . . .	14980	14830	−150
H_3PO_4	14910	14830	−80
$HOPOH_2$	15460	15160	−300
HF	16120	16270	+150

The table shows, among other things, that the explanation of the fact that some weak acids, as HF, $HOPOH_2$, H_3PO_4, have higher heat of neutralisation than the strong acids, is to be found in the development of heat in dissociation shown by the table of p. 221.

Another deduction from the principles mentioned above is that the conductivity of an electrolyte may have a negative temperature coefficient, if the temperature be sufficiently raised. The resistance of an electrolyte depends upon (1) the friction of the moving ions, (2) their number or the dissociation ratio, and both of these vary with the temperature. According to Ostwald's dissociation formula, if δ be the dissociation ratio,

$$\frac{\delta^2}{(1-\delta)v}=k$$

and

$$\frac{d \log_e k}{dt}=\frac{1}{T}+\frac{A}{R}\frac{W}{T^2}.$$

Assuming, for the sake of simplicity, that the right-hand side does not vary with the temperature, and further, supposing that the electrolyte is only slightly dissociated, so that δ is small compared with unity, and v being constant, we get

$$\frac{2d \log_e \delta}{dt}=\text{const.}= -2b\ dt.$$

Whence

$$\delta_t=Ae^{-bt}.$$

[1] ? $2H_2+O_2=2H_2O+27040$ cal.; or $H,H,H,H+O,O,=2H_2O+27040$ cal.

The friction of the ions may be taken to be the same for most acids, since the motion is due mainly to the hydrogen, so that this may be put equal to a constant multiplied by $(1+at)$, where a is the temperature coefficient of the fluidity.[1]

Whence [2]

$$R_t = A_1 e^{-bt}(1+at).$$

This function assumes a maximum value when

$$(1+at)b = a \text{ or } at = \frac{1}{b} - \frac{1}{a}.$$

There are obviously many rough-and-ready approximations in the course of this proof, but the remarkable fact remains that this behaviour of electrolytes of low conductivity was actually verified in the case of hypophosphoric acid and phosphoric acid, which gave maxima of conductivity at 54° and 74° respectively. A rough calculation of the temperatures at which the conductivity would reach its maximum value for other electrolytes gives the following results :—

Name	Concentration	α	β	Temperature of Maximum Conductivity
$CHCl_2COOH$ . . .	0·2	0·0162	0·0083	81°
HF	0 2	0·0162	0·0117	56°
C_3H_7COOH . .	0·2	0·0162	0·0042	195°
HNO_3	0·5	0·0157	0·0014	668°
NaOH . . .	0·5	0·0213	0·0011	882°
$\frac{1}{2}CuSO_4$ . . .	0·5	0·0256	0·0058	151°
KI	0·5	0·0231	0·0024	391°
NaCl	0·5	0·0253	0·0012	808°

It will be seen from the foregoing sketch that the various numerical relations between widely different properties of solutions and the agreement of calculated with observed results are so striking that the further development of the theory will be looked for with great interest. The part which the solvent plays is still unexplained, though it is becoming more and more clearly defined.

§ d.—*Electro-Chemical Thermodynamics ;*

§ e.—*Electric Endosmose ;*

§ f.—*The Theory of Migration and Ionic Velccities ;* and

§ g.—*Numerical Relations*

are reserved for the present.

[1] According to Arrhenius, it is the temperature coefficient of molecular conductivity in infinite dilution.

[2] A formula identical with this was suggested to me by a consideration of the numerical results for temperature variation of fluidity and conductivity of certain electrolytes. (*Proc. Camb. Phil. Soc.* vol. 7, p. 21, 1889.)

Report of the Committee, consisting of Sir H. E. Roscoe, Mr. J. N. Lockyer, Professors Dewar, Wolcott Gibbs, Liveing, Schuster, *and* W. N. Hartley, Captain Abney, *and* Dr. Marshall Watts (*Secretary*), *appointed to prepare a new series of Wave-length Tables of the Spectra of the Elements and Compounds.*

The 'Table of Corrections' given herewith has been obtained by a careful comparison of Professor Rowland's photographic map of the solar spectrum with the maps of Ångström and Cornu, upon which the tables already given in these Reports are based.

Table of Corrections to be applied to reduce Angström's and Cornu's Numbers to the Standard of Rowland's Map.

Wave-length	Correction	Wave-length	Correction
Above 6930	+1·7	From 4970 to 4935	+1·0
From 6930 to 6880	+1·6	„ 4935 to 4865	+0·9
„ 6880 to 6820	+1·5	„ 4865 to 4740	+1·0
„ 6820 to 6800	+1·4	„ 4740 to 4650	+0·9
„ 6800 to 6765	+1·3	„ 4650 to 4470	+0·8
„ 6765 to 6720	+1·2	„ 4470 to 4380	+0·7
„ 6720 to 6660	+1·1	„ 4380 to 4170	+0·6
„ 6660 to 6230	+1·0	„ 4170 to 4130	+0·7
„ 6230 to 6180	+0·9	„ 4130 to 4100	+0·8
„ 6180 to 6155	+1·0	„ 4100 to 4060	+0·7
„ 6155 to 6135	+1·1	„ 4060 to 4040	+0·6
„ 6135 to 6130	+1·0	„ 4040 to 3850	+0·7
„ 6130 to 6110	+0·9	„ 3850 to 3730	+0·6
„ 6110 to 6080	+1·0	„ 3730 to 3720	+0·5
„ 6080 to 6060	+1·1	„ 3720 to 3660	+0·4
„ 6060 to 6000	+1·0	„ 3660 to 3640	+0·8
„ 6000 to 5970	+0·9	„ 3640 to 3620	+0·6
„ 5970 to 5810	+1·0	„ 3620 to 3530	+0·8
„ 5810 to 5780	+0·9	„ 3530 to 3480	+0·6
„ 5780 to 5610	+1·0	„ 3480 to 3470	+0·8
„ 5610 to 5540	+1·1	„ 3470 to 3440	+0·7
„ 5540 to 5485	+1·0	„ 3440 to 3420	+1·1
„ 5485 to 5435	+0·9	„ 3420 to 3360	+1·7
„ 5435 to 5350	+1·0	„ 3360 to 3330	+2·5
„ 5350 to 5335	+0·9	„ 3330 to 3290	+2·2
„ 5335 to 5325	+1·0	„ 3290 to 3280	+2·0
„ 5325 to 5300	+0·9	„ 3280 to 3240	+1·9
„ 5300 to 5175	+1·0	„ 3240 to 3220	+1·8
„ 5175 to 5150	+0·9	„ 3220 to 3190	+0·8
„ 5150 to 4990	+0·8	„ 3190 to 3160	+0·4
„ 4990 to 4970	+0·9		

The spectra of cobalt and nickel now given are upon Ångström's scale, but the absorption spectrum of iodine rests upon the numbers of the Potsdam catalogue of 300 solar lines, the numbers of which agree very closely indeed with those of Rowland, as is seen in the following comparison:—

	Potsdam Catalogue	Rowland's Map
C (Hydrogen)	6563·14	6563·042
D_1(Sodium)	5896·25	5896·156
D_2(Sodium)	5890·23	5890·188
E_1(Iron)	5270·55	5270·497
E_2(Iron)	5269·90	5269·720
b_1(Magnesium)	5183·93	5183·798
b_3(Iron)	5169·33	5169·159

COBALT.[1]

A number printed in italics signifies that the wave-length was directly measured by means of a grating. The numbers given under 'Oscillation Frequency' are *in vacuo.*

* Double. † With cobalt chloride in oxyhydrogen flame. ‡ Also a nickel line. § Also an iron line.

Wave-length	Intensity and Character: Spark	Intensity and Character: Arc	Oscillation Frequency	Wave-length	Intensity and Character: Spark	Intensity and Character: Arc	Oscillation Frequency
3997·3	1	10	25009	*3656·1*	1	3	27343
†*3994·7*	10	8	25026	*3654·0*	1		27359
3991·4		3	25046	*3648·8*	1		27398
3990·2		3	25054	*3642·7*	3	3	27444
3987·1		1	25073	*3641·1*	1	1	27456
†3978·7	8	8	25126	*3638·9*	1	3	27472
3974·1		3	25155	*3636·1*	1	1	27494
3968·8	1		25189	*3634·2*	4	1	27508
3957·7	1	4	25259	*3632·2*	1	1	27523
3955·7	1	1	25272	†*3627·3*	6	10	27560
3952·4	1	1	25293	3614·8	1	1	27655
3944·9	1	1	25341	*3611·3*	1	1	27682
†*3940·9*	1	6	25367	§*3605·0*	6	8	27731
†*3935·5*	6	3	25402	*3601·6*	6	10	27757
3916·2	1	1	25527	‡*3594·4*	6	10	27812
†3909·0	1	4	25574	*3586·7*	10	8	27872
3905·2	1	4	25599	§*3584·7*	6	8	27888
3894·3	3		25671	*3577·4*	1	3	27945
†*3893·4*	10	10	25677	†*3574·9* }	10	10	27964 }
3884·0	1		25739	†*3574·5* }			27967 }
3881·0	6	10	25759	†*3568·9*	10	10	28011
3876·1	1	3	25791	†*3564·5*	6	10	28046
†*3873·2*	6 }	10	25810	3562·3	1		28063
†*3872·4*	8 }		25816	†*3560·5*	8	6	28077
3860·5	4		25895	*3552·4*	1	1	28141
†*3844·8*	10	8	26001	*3550·1*	4	6	28159
†*3841·4*	8	4	26024	3548·0	1	1	28176
3830·3	1		26099	*3544·7*	1	1	28202
§*3815·7*	1		26200	*3542·8*	4	3	28217
§*3815·1*	1		26204	†*3532·8*	4	6	28297
3807·3	1	3	26258	‡*3529·3*	6	10	28325
3777·0	1	3	26468	†*3528·4*	1	4	28333
3774·0	1	3	26489	*3526·3*	4	6	28349
3769·7	1		26520	†*3522·9*	6	6	28377
3753·9	1		26631	§*3520·9*	6	8	28393
†*3745·8*	10		26689	*3519·5*	3	6	28404
3735·2	1		26764	*3517·7*	6	8	28419
3732·8	1	3	26782	†*3512·0*	4	6	28465
3731·8	4	3	26789	‡*3509·7*	1 }	6	28483 }
3729·8	3	3	26803	†*3509·3*	4 }		28487 }
3711·6	1		26935	†*3505·9*	10	8	28517
†*3703·5*	8	10	26993	3503·4	1		28535
3701·7	6	1	27007	*3502·0*	3 }	10	28546
3692·8 }	6	6	27072	†*3501·6*	10 }		28549
3692·4 }			27075	*3501·0*	4 }		28554
3690·2	1	1	27091	*3496·0*	3	6	28595
3682·5	6	8	27147	†*3495·1*	6	10	28602
3680·8	1		27160	*3490·6*	3	4	28639
3661·6	6	*4	27303	†*3488·8*	10	10	28654

[1] Liveing and Dewar, *Phil. Trans.* clxxix. 231 (1888).

COBALT—*continued.*

Wave-length	Intensity and Character: Spark	Intensity and Character: Arc	Oscillation Frequency	Wave-length	Intensity and Character: Spark	Intensity and Character: Arc	Oscillation Frequency
3484·7	4	4	28688	*3319·0*	6	4	30120
†*3482·7*	6	10	28704	*3313·6*	4	3	30169
3478·0	1	3	28743	‡*3311·7*	3	3	30187
3476·0	1	8	28760	3309·1	3		30211
†*3473·4*	10	10	28781	3308·2	1	1	30219
†‡§*3465·2*	8	10	28849	*3306·5*	1	1	30234
†*3462·2*	8	8	28874	3303·2	1	1	30264
3460·6	3	4	28882	*3294·2*	1		30347
3454·6	4	6	28938	3286·6	3	3	30417
‡†*3452·9*	8	8	28953	3284·2	1		30439
3448·9	3 }	10	28986	*3282·9*	8	6	30452
†*3448·6*	6 }		28989	3278·5	3	1	30492
‡†*3445·7*	4	6	29013	3277·2	1	4	30504
†*3443·0*	6	6	29036	3276·0	1	1	30516
3442·3	1	6	29047	3271·3	2	1	30560
3438·2		1	29076	3264·4	*3	3	30624
‡3436·8	*3	4	29088	3262·7		1	30640
‡*3432·9*	6 }	10	29121	3261·7	1	3	30649
†*3432·4*	6 }		29126	*3260·1*	4	3	30664
3431·3	3 }	8	29135	*3253·7*	4	4	30725
†*3430·9*	4 }		29138	3249·6	1	3	30764
‡*3423·2*	*4	6	29204	§*3246·7*	6		30791
†*3416·5*	4	8	29261	§*3243·4*	4	3	30822
3415·2	1		29272	*3236·7*	3	4	30886
3414·2		8	29281	3235·2	3	3	30900
3412·0	6 }	10	29300	*3232·4*	3	4	30927
†*3411·7*	8 }		29302	3226·5	1	1	30984
†*3408·6*	6	10	29329	3218·7	3	4	31059
3406·1	1		29350	3210·1	1	1	31142
‡†*3404·5*	8	10	29364	3188·0	3	3	31358
3394·8	6	10	29448	3181·7	3	3	31420
3394·2	6		29453	*3176·6*	4	3	31470
3387·6	6	10	29511	3174·8	1	4	31488
3387·1	6	10	29515	3169·5	3	3	31541
3384·7	4	8	29536	3164·3	1	1	31593
‡*3380·0*	1	10	29577	3161·3	1	1	31622
3378·0	2	1	29594	3159·2	3	3	31644
3376·6	1	2d	29607	*3158·2*	6	6	31654
3370·4	4	4	29661	*3154·2*	8	6	31694
3366·6	6	10	29695	3152·3	1	1	31713
3362·3	1	1	29733	3148·9	3	4	31747
‡*3360·8*	1	6	29746	*3146·6*	6	6	31770
3353·9	8	10	29807	*3139·5*	6	6	31842
3352·3	4		29821	*3136·8*	6	8	31869
3348·9	1	3	29852	*3130·4*	4	1	31935
3347·7	3	3	29862	3126·7	1	1	31972
3346·4	3	3	29874	*3121·1*	8	8	32030
3342·2	3	3	29911	3113·0	3	3	32113
3340·8	1 }	3	29924	3109·5	1	1	32149
3340·2	1 }		29929	3109·0	1	1	32154
3339·3	3	3	29937	3103·3	3	3	32213
3333·6	8	10	29989	3101·8	1		32228
3329·0	1	1	30030	3097·6	4	6	32273
3326·4	3	3	30053	3089·0	4	4	32363
3324·8	3	3	30068	3086·3	8	8	32392
‡*3321·7*	4	4	30096	3082·1	6	6	32436

COBALT—*continued.*

Wave-length	Intensity and Character		Oscillation Frequency	Wave-length	Intensity and Character		Oscillation Frequency
	Spark	Arc			Spark	Arc	
3078·9	1	1	32470	§*2806·7*	4		35618
3073·4	1	1	32528	§2803·3	1	2	35661
3072·0	8	8	32542	*2801·7*	*3		35681
3071·8		1	32545	2798·4	1	1	35723
3064·0	1	4	32627	2796·6	1		35746
3063·0	1	3	32638	2796·3	1		35750
3061·4	8	6	32655	2795·8	1		35756
3059·6	1	1	32674	2793·4	6		35787
3050·6	4	6	32771	§2789·1	1		35842
3048·6	6	6	32792	*2786·9*	*3		35871
3043·6	6	6	32846	2785·7	*3		35886
3042·2	1	3	32861	2785·2	*3		35892
3034·0	8	3	32950	2778·5	1	1	35979
3033·8		3	32952	*2775·7*	8		36015
3017·0	6		33136	‡2774·8	*3	1	36027
3015·2	1	1	33155	*2768·6*	4	1	36108
3013·2	4	4	33177	*2766·5*	3		36135
3010·3	1	3	33209	2766·0	3	4	36141
3008·5	*1	1	33229	2763·9	3	4	36169
3000·1	1	2	33332	*2761·0*	1	3	36207
2994·7	1		33382	2757·1	1	1	36258
2989·1	6	6	33445	2744·7	3	3	36422
2986·5	6	6	33474	2738·6	1		36503
2983·3	1	1	33510	2734·3	*3		36560
2971·2	*1		33646	2732·6	1		36583
2954·1	*10		33841	2730·7	1	1	36609
2942·5	*8	8	33974	2728·8	*4		36635
2930·0	*8		34119	2727·5	*4		36653
2929·0	1	1	34131	*2720·6*	*4		36746
2927·2	1	1	34152	2715·3	3	6	36817
2918·1	*6		34258	2714·5	1		36828
2906·5	1	3	34395	*2713·9*	6		36836
2899·3	1	6	34480	§*2708·6*	1	1	36908
2897·5	*3		34502	*2707·4*	*3		36925
2890·0	8	1	34591	§*2706·9*	*1		36932
2886·0	3	4	34639	§*2706·2*	*4		36941
2883·1	*1		34674	*2701·9*	4		37000
2881·3	1	6	34696	*2696·4*	1		37075
2879·9	*1		34713	2696·0	1		37081
2870·4	8		34827	2695·9	1		37082
‡2865·1	1		34892	*2695·3*	1	6	37091
2862·2	1	3	34927	*2694·1*	8	1	37107
2849·8	1	3	35079	*2692·5*	3		37129
§2847·9	*3		35102	*2689·2*	3		37175
2845·2	1		35136	‡*2684·0*	*6		37247
2836·7	1	1	35241	2681·5	1		37281
2834·3	6		35271	2679·8	3		37305
2824·5	8	8	35393	2679·0	1	4	37316
2823·2	1		35409	2677·4	3		37338
2822·7	*3		35416	2675·4	*6	4	37366
2821·1	*1	3	35436	‡2670·1	1		37441
2819·4	1	1	35457	*2669·7*	3	1	37446
2818·3	1	1	35471	*2662·7*	8	1	37545
2815·8	*1		35502	2653·3	6		37677
2815·2	4	6	35510	2648·4	8	10	37747
2810·3	6		35572	2646·1	3	6	37780

COBALT—*continued.*

Wave-length	Intensity and Character: Spark	Intensity and Character: Arc	Oscillation Frequency
2644·4	1	1	37804
2642·7	*1	1	37829
2634·5	3		37946
2631·9	6	1	37984
‡2628·4	*1(?)		38034
2627·3	1	6	38050
2626·6	*1	1	38060
2621·7	*1	4	38131
2619·3	4	1	38166
2618·5	4	8	38178
2613·8	6	1	38247
2613·0	4		38258
2605·3	1	2	38371
2605·2	4	4	38373
2603·9	3	3	38392
2600·3	1	3	38445
§2598·8	1	1	39467
2592·9	1	1	38555
‡2586·8	8	1	38646
2584·8	1	3	38676
2582·6	3		38709
2581·7	6	1	38722
‡*2579·8*	10	3	38751
2574·4	6	3	38832
2573·1	1	4	38851
2571·9	1	4	38870
2569·3	6		38909
2567·0	1	6	38944
2565·0	1		38974
2563·6	10	1	38995
2561·7	1	10	39024
2559·6	6	1	39056
2558·9	8	1	38067
2556·9	4	4	39098
2556·3	6		39107
2553·1	1	4	38156
‡2552·7	1	4	39162
2552·2	4		39170
§2550·1	4		39202
§2549·7	*1	4	39208
2548·9	1	4	39220
2546·3	8		39260
2545·7	1	3	39270
2544·6	3	4	39286
2544·2	1	6	39293
2543·9	1		39297
2541·5	8	8	39334
2540·2	6		39355
2537·0	3	1	39404
2536·1	1	4	39418
2535·5	3	4	39427
2533·4	8		39460
2531·7	1	10	39487
2529·6	6	6	39519
2528·1	8	8	39543
2524·5	8		39599
2524·2	1	10	39604
2522·5	4		39681
2520·7	3	10	39659
2519·3	10		39681
2517·3	3	8	39712
2516·9	4		34719
2511·7	1	1	39801
2511·4	1		39806
‡*2510·5*	10	10	39820
2509·4	1		39837
2507·5	4	4	39868
2505·8	10	10	39895
2504·1	1	6	39922
2501·7	*3	1	39960
2500·2	3	6	39984
2498·2	4		40016
2497·1	6	6	40034
2496·3	1	8	40046
2495·1	1	4	40066
2494·4	1	3	40077
2490·4	1	6	40141
2489·8	6	6	40151
2486·9	1		40198
2486·7	1		40201
§*2485·9*	6		40214
2484·8	6		40232
2484·4	1		40238
2484·1	1		40243
2483·2	1	4	40258
2478·6	3		40332
2477·8	4		40345
§*2477·1*	4		40357
2476·9	1		40360
2476·2	1	6	40371
2476·0	1		40375
2474·9	*1		40393
2473·5	*1		40415
2472·5	1	8	40432
2469·7	1	6	40478
2469·0	1	1	40489
2466·5	8		40530
2463·7	10	4	40576
2460·8	1		40624
2460·3	1	6	40632
2459·0	6		40654
2455·7	1	8	40708
2453·6	1		40743
2453·3	1	3	40748
2452·7	1		40758
2452·0	1	1	40770
2449·4	8		40813
2448·7	4		40825
§*2447·3*	8	3	40848
2445·6	6	1	40876
2443·3	6	3	40915
2442·0	8		40937

COBALT—*continued.*

Wave-length	Intensity and Character: Spark	Intensity and Character: Arc	Oscillation Frequency	Wave-length	Intensity and Character: Spark	Intensity and Character: Arc	Oscillation Frequency
2441·2	3	4	40950	§_2374·8_	4	1	42095
2440·6	1	4	40960	2372·6	3	3	42134
2439·7	*1		40975	2371·8	3	4	42148
2438·5	3	6	40995	_2371·5_	6	4	42153
2437·9	*1		41005	2370·1	3	4	42178
_2436·5_	6 }	8	41029	2366·6	1	3	42219
2436·2	1 }		41034	_2363·3_	10	6	42299
2435·8	1	3	41041	2361·2	1	1	42339
2434·6	3	8	41061	2360·8	1	1	42346
_2432·0_	10	10	41105	2360·3	4		42355
2430·0	1		41139	_2360·2_	3	1	42357
_2429·6_	3	3	41145	2360·0	4	1	42360
_2427·8_	6		41176	_2357·7_	4	4	42402
_2425·7_	3	1	41212	_2353·0_	10	6	42486
_2424·5_	4	*10	41232	_2352·1_	1	6	42502
_2423·2_	6	1	41254	2351·5	1	3	42513
2422·1	1	4	41273	§‡2350·6	3	3	42530
2421·6	1	1	41281	2348·1	1		42575
_2420·3_	10	1	41303	2347·4	3		42588
_2418·1_	6	4	41341	_2347·0_	6	3	42595
_2417·2_	6	6	41356	2346·7	1	3	42600
_2416·5_	6	3	41368	‡2346·2	4	1	42609
_2415·7_	4		41382	2345·2	3	3	42628
2415·5	6		41386	2344·3	4		42644
_2414·8_	3	8	41397	§_2344·0_	6		42649
2414·1	3	8	41409	‡_2340·8_	8		42708
_2413·7_	6	4	41416	2338·8	3	4	42744
‡_2412·2_	1	6	41442	2338·4	1	4	42751
_2411·2_	8	10	41494	_2337·6_	8	4	42766
_2408·3_	6	4	41509	‡2336·6	3	1	42784
_2407·8_	6		41518	_2335·9_	6	4	42797
_2407·1_	6	*10	41530	2333·7	1	1	42838
2406·9	1		41533	‡_2330·0_	6	3	42905
_2405·1_	4	1	41561	2328·7	1	1	42929
2404·0	4	1	41583	2327·3	3		42955
_2403·8_	6	4	41587	‡_2326·1_	6	4	42977
2403·3	1	1	41596	_2325·9_	6	3	42981
2402·4	1	1	41611	‡_2324·0_	6	4	43016
‡2401·6	1 }	8	41625	‡2321·0	1	3	43085
_2401·3_	1 }		41630	2319·6	1	4	43098
_2397·8_	4	3	41691	2318·2	1		43105
_2396·9_	10	3	41707	‡2316·8	6	3	43150
2395·1	4	4	41738	‡2315·5	1	4	43174
2393·4	4	1	41768	_2314·5_	8	3	43193
‡2392·1	4	4	41787	‡_2313·5_	8	6	43211
2391·5	1	4	41801	2313·1	4		43219
2389·1	6	4	41843	2312·1	3	3	43238
2388·4	10	1	41855	‡_2311·1_	10	6	43256
_2388·3_	3	4	41857	2310·4	1	1	43269
_2386·1_	6	1	41895	_2307·4_	*10	8	43326
_2385·9_	8	4	41899	2306·4	1		43344
_2382·9_	8	4	41952	‡2305·6	1		43359
‡2381·7	3		41973	2303·8	1		43393
_2381·3_	8	4	41980	2300·8	3	4	43450
2380·3	1	1	41997	2800·3	3	3	43459
_2378·1_	10	8	42036	2299·3	4	1	43478

COBALT—*continued.*

Wave-length	Intensity and Character		Oscillation Frequency	Wave-length	Intensity and Character		Oscillation Frequency
	Spark	Arc			Spark	Arc	
2298·3	1	1	43497	2272·0	1		44000
2296·9	3	3	43524	2270·5	1		44030
2295·5	3	4	43550	‡2266·2	8		44113
2293·0	6	8	43598	2259·7	8		44240
2291·5	6	4	43626	2256·4	8		44305
2290·9	1	1	43638	2253·2	1		44367
2289·9	1	1	43657	2244·8	6		44533
2287·8	1	3	43697	2234·4	1		44741
2285·7	*8	8	43737	2231·5	1		44799
2283·1	3		43787	2229·5	1		44839
2281·9	1		43810	2219·6	1		45039
2281·5	4		43817	2215·9	1		45114
2280·1	3		43844	2214·1	1		45151
2278·1	1		43883	2205·7	1		45323
2275·9	1		43925	2298·2	1		45477
2275·1	1		43941	2293·1	1		45583
‡2274·2	1	1	43958	2291·9	1		45608
‡2273·3	3		43975	2290·2	1		45643

NICKEL.[1]

* Double. † Also in oxyhydrogen flame. ‡ Also a cobalt line. § Also an iron line.

Wave-length	Intensity and Character		Oscillation Frequency	Wave-length	Intensity and Character		Oscillation Frequency
	Spark	Arc			Spark	Arc	
3857·8	8	8	25913	*3624·1*	1	3	27585
3848·9	3		25973	†*3618·8*	10	10	27625
3837·5	3		26050	†*3612·1*	6	6	27676
3831·7	1		26090	*3609·8*	8	8	27694
†*3806·6*	8	6	26263	*3608·6*	1	1	27703
†*3783·0*	6	4	26426	*3601·4*	3		27758
†*3775·0*	6	6	26482	†*3597·0*	10	10	27792
3768·9	8		26525	*3587·2*	*3	3	27868
3736·1	8	8	26758	*3576·1*	8		27955
3724·2		1	26843	§†*3571·2*	8	8	27993
§*3721·6*	6		26862	†*3565·7*	10	6	28036
3710·9		1	26940	*3561·1*	1		28072
3697·2		1	27039	*3552·8*	1		28138
3694·6		1	27058	*3550·8*	1		28154
3687·6	1		27110	*3547·5*	6	6	28180
3673·4	3	4	27215	*3529·9*	1	1	28321
3671·5		1	27229	‡*3529·2*	1	3	28326
3669·7	1	8	27242	*3527·1*	3	1	28343
3666·9		1	27263	3526·0	3		28352
3663·4	3		27289	†*3523·9*	10	10	28369
3659·3		3	27319	*3519·1*	6	6	28407
3657·5		1	27333	3518·0	1		28416
3655·2		1	27350	†*3514·4*	10	10	28445
3653·0		6	27366	§*3513·3*	8		28454
3634·9		4	27503	†‡*3509·7*	10	10	28483

[1] Liveing and Dewar, *Phil. Trans.* clxxix. 231 (1888).

NICKEL—*continued.*

Wave-length	Intensity and Character		Oscillation Frequency	Wave-length	Intensity and Character		Oscillation Frequency
	Spark	Arc			Spark	Arc	
3507·3	1	1	28503	*3250·1*	4	3	30760
3505·9	1	3	28514	3247·8	1	1	30781
3501·8	3	4	28548	*3242·6*	6	6	30830
3500·0	8	8	28562	*3234·2*	6	6	30910
†*3492·3*	10	10	28625	§*3232·6*	8	10	30925
3485·2	3	3	28684	*3226·3*	1	1	30986
3483·1	8	8	28707	*3224·6*	4	4	31002
3471·9	8	8	28793	*3221·1*	3	3	31036
3470·8	*3	1	28803	*3217·4*	3		31071
3468·9	3	4	28818	3216·6	1	1	31079
3466·8	3	3	28836	3216·0	1		31081
‡*3465·1*	6	8	28850	§*3213·7*	3		31107
†*3461·1*	10	10	28883	3212·3		1	31121
3457·9	10	10	28911	*3201·5*	1		31226
†3457·7	*3	8	28913	§*3196·6*	6	6	31273
3453·5	4	4	28948	*3194·9*	1	4	31290
†*3452·9*	3	4	28953	*3183·8*	1	6	31399
‡†*3452·3*	10	4	28958	§*3182·6*	1	1	31411
3445·7	10	10	29013	*3181·2*	1		31425
3441·6	1		29048	*3179·2*	*6	6	31445
‡*3436·7*	8	8	29089	*3158·9*	*3	3	31656
‡*3433·0*	10	10	29121	*3145·5*	3	4	31781
‡*3423·1*	10	8	29205	*3134·0*	1	1	31898
3420·6	1	1	29224	§*3133·6*	10	10	31902
3413·8	10	8	29284	*3113·7*	3	4	32106
†*3413·4*	4	10	29288	§*3105·0*	3	6	32196
3412·9	8	8	29292	*3101·4*	8	8	32233
3409·0	1	3	29325	*3101·1*	6	6	32236
3406·6	6	6	29346	*3098·6*	4		32262
‡*3404·5*	3	1	28364	*3096·6*	4		32283
3402·8	1		29379	*3086·6*	8		32389
3400·5	1	3	29399	*3080·3*	6	6	32455
3392·4	8	8	29469	*3064·2*	6	6	32625
3390·4	8	8	29486	§*3057·2*	8		32700
‡*3380·0*	10	10	29577	*3053·9*	8	6	32735
3374·0	4	4	29630	*3050·4*	8	8	32773
3373·6	1	4	29633	§*3044·5*	4	4	32836
3373·3	6	6	29636	*3037·5*	8	8	32912
3371·3	6	4	29653	3031·4	4	4	32978
§*3368·9*	8	6	29674	*3018·8*	6		33116
†*3367·2*	1	8	29689	*3011·5*	10	10	33196
3365·5	4	4	29704	*3003·2*	8	8	33288
3365·1	4	4	29708	*3002·1*	8	8	33300
3361·0	3	6	29744	§*2994·1*	6	6	33389
‡*3360·9*	6	8	29745	*2992·2*	6	8	33410
3358·1	1	3	29770	2988·0	1		33457
3349·8	3		29844	*2987·7*	*3		33460
‡*3321·6*	6	4	30097	*2983·6*	4	6	33506
3319·7	6	6	30114	§*2981·2*	6	6	33533
3315·1	6	6	30156	2968·7	*3		33674
3312·4	1		30180	2957·8	1		33799
‡*3311·8*	3	1	30186	2954·5	*3		33836
3290·1	1		30385	*2947·1*	4		33921
3282·2	3	4	30458	*2943·5*	8	10	33963
3274·4	1		30531	§2938·7	1	1	34018
§*3270·6*	1	1	30566	§*2936·3*	*8		34046

NICKEL—*continued.*

Wave-length	Intensity and Character		Oscillation Frequency	Wave-length	Intensity and Character		Oscillation Frequency
	Spark	Arc			Spark	Arc	
2934·3	1		34069	2557·5	1		39088
§*2928·4*	*6		34138	*2554·7*	4		39131
2918·8	*1		34250	‡*2552·6*	*1	4	39163
2913·2	8	8	34316	*2549·1*	1	1	39217
2906·9	3	6	34390	*2545·4*	6	6	39274
2900·6	1		34465	§*2543·2*	3		39308
2898·8	1		34486	2539·5	1	6	39365
2889·1	1		34602	2524·1	1		39605
2882·2	*1		34685	2520·0	1	1	39670
2880·9	*1		34700	‡*2510·6*	10	8	39818
‡2865·1		6	34892	*2509·6*	1		39834
2863·3	8		34914	‡*2505·9*	6		39893
2823·9	1		35401	2496·9	1	1	40037
2820·8	6	10	35440	*2483·6*	*6	6	40251
2807·8	1		35604	2476·6	1	1	40365
2806·0	*1		35626	§*2472·8*	8	6	40427
2805·0	8	6	35639	§2471·8	1	8	40443
‡*2774·7*	*4		36028	2455·4	4	1	40713
2760·4	1		36215	2453·7	1	8	40741
2758·7	4		36237	2448·1	3		40835
2708·3	4	4	36913	§2441·5	1	10	40945
§2701·2	3	1	37010	*2437·5*	*10	6	41012
2700·4	1	1	37021	§2433·9	1	6	41073
2690·2	1		37161	§2433·2	4		41085
‡2684·0	8		37247	2431·2	1		41118
2678·8	6		37319	2426·8	1		41193
2674·4	1		37380	2423·4	1	6	41251
2672·1	1		37412	2420·8	1	8	41295
§2670·0	3		37442	2419·0	1	6	41326
2664·9	1		37513	*2416·0*	*10	8	41377
2659·5	3	3	37590	2412·8	3	6	41432
2655·6	6	1	37645	‡*2412·1*	1	6	41444
2648·6	1	1	37744	*2404·8*	1	1	41570
2646·8	6	6	37770	‡2401·7	1	6	41623
2643·4	1		37819	§*2400·1*	1		41648
2641·0	1		37853	2397·2	1		41741
§*2639·5*	6		37874	§2394·7	1	6	41745
2636·8	1		37913	*2394·3*	8	8	41752
2632·4	1		37971	§*2394·0*	8	8	41757
2628·4	1		38034	2392·6	4	6	41701
2626·3	1		38065	‡2392·0	1	1	41792
§*2614·9*	6		38231	2388·7	1	1	41850
2609·6	6		38308	§*2388·5*	4	1	41853
§2606·7	1		38351	*2387·5*	6	4	41871
§*2606·1*	1		38360	*2386·3*	1	6	41892
2600·8	1		38438	†§2381·8	8	3	41971
§2593·1	3		38552	2378·6	1	1	42027
‡2586·7	1	1	38647	2375·6	1	6	42080
2584·4	3		38682	*2375·0*	8	4	42091
2583·5	4		38695	2370·9	1	1	42164
‡2579·9	1	1	38749	2369·5	4		42189
2575·7	4	4	38812	2368·9	3	1	42199
2571·7	1	1	38873	*2367·0*	4	3	42233
2568·2	1	1	38926	§*2366·1*	4	1	42249
2565·7	*4		38964	*2358·5*	1	6	42337
2559·8	4	3	39053	*2355·9*	6	6	42434

NICKEL—*continued.*

Wave-length	Intensity and Character		Oscillation Frequency	Wave-length	Intensity and Character		Oscillation Frequency
	Spark	Arc			Spark	Arc	
‡2350·5	1	1	42531	2277·8	6	4	43888
§2349·8	*1	1	42544	*2277·0*	6	1	43904
2347·6	1	4	42584	2276·3		3	43917
‡2346·2	1	4	42609	§*2275·7*	3	4	43929
2345·0	1		42631	‡§2275·0	4	3	43942
§*2344·7*	8	6	42637	‡2274·1	6	6	43960
2343·5	1		42658	‡2273·2	1	1	43977
2343·0	4	1	42668	2272·3	1		43995
‡*2340·7*	8		42709	2271·1	1	6	44018
2337·1	1	3	42775	2270·3	1		44033
‡2336·6	1	6	42784	*2269·9*	*10	10	44041
2336·2	*6	1	42792	*2269·1*	1	6	44057
2334·1	8	1	42830	‡2266·1	1	3	44115
‡2330·1	1		42904	§2264·8	3		44140
2329·6	4	8	42913	§*2264·1*	8	10	44154
‡*2326·0*	8	6	42979	§2263·1		4	44173
2325·5	4	8	42989	2262·6	1	1	44183
‡2324·0	*1		43016	2261·1	1	4	44213
2323·3	*1		43029	§2260·3	1		44228
2322·3	1	6	43048	2259·4	1	6	44246
2321·6	1	3	43061	2258·9	3		44256
‡*2321·0*	4	8	43072	2257·6	4	6	44281
2319·3	6	6	43103	*2255·7*	6	3	44318
2318·0	6		43128	*2254·7*	6	6	44338
‡2316·8	1	6	43150	2253·9	1		44354
‡*2315·6*	*10	6	43172	*2253·5*	*10	8	44362
‡*2313·6*	3	6	43210	2252·6	1		44379
2313·4	1	6	43213	2251·4	1	4	44403
2312·5	6		43230	§2251·1	1	1	44409
2311·8	4	6	43243	§2250·5	1	1	44421
‡2311·2	1		43254	2250·2	1		44427
2310·6	*3	6	43266	2249·2	1		44446
2308·1	6	1	43312	§2248·8	1	4	44454
‡2305·7	1		43358	2247·4	1		44482
2304·8	6		43374	*2246·6*	3		44498
2303·3	6	4	43403	*2245·9*	*1		44512
2302·5	8		43418	2244·4	*1	8	44541
2302·0	8		43427	§*2242·2*	1	3	44585
2301·5	1		43437	2241·2	1		44605
2299·8	6		43469	2239·8	*1		44633
2299·2	6		43480	2238·2	*1		44665
2298·0	*6	1	43503	2237·6	*1		44677
2297·1 }	6	1	43520	2235·5	1		44719
2296·7 }			43527	2233·5	3		44759
2296·2	8		43537	2231·2	1		44805
2295·3	1		43554	‡§2229·6	*4	6	44837
2292·7	1	1	43603	§2227·2	1	8	44885
2290·7	1		43641	2226·7	1		44895
2289·6	4	4	43662	*2225·8*	6	6	44914
2287·4	8	1	43704	§2225·3	1		44924
2286·8	8	6	43716	*2224·3*	6	8	44944
2284·8	1		43754	*2223·8*	6		44954
2283·7	1	1	43775	*2222·3*	6	8	44984
2280·6	*1		43835	2221·7	1		44996
2279·2	1	0	43862	2221·3	1	3	45004
2278·4	*8	6	43877	2220·6	3		45019

NICKEL—*continued.*

Wave-length	Intensity and Character		Oscillation Frequency	Wave-length	Intensity and Character		Oscillation Frequency
	Spark	Arc			Spark	Arc	
2219·8	6	1	45035	2197·2	*1	6	45498
2219·0	1		45051	2193·2	1		45581
2217·4	3	3	45084	2190·6	1	4	45635
2216·0	6	3	45112	2190·0	1	4	45647
‡*2215·8*	8	10	45116	*2188·2*	3	1	45685
2212·5	4	3	45183	2185·0	6	1	45752
§2211·4	1	3	45206	2184·2	6	6	45769
§2210·5	4	4	45224	2182·8	1	6	45798
2209·8	*8	6	45239	2179·9	4		45859
2206·1	8	8	45314	2179·4	1		45869
2205·2	*6	6	45333	2176·7	3		45926
2203·0	*1		45378	*2176·0*	3		45941
2200·8	8	4	45424	2174·4	4	6	45975
2198·4	3	4	45473	2173·8	4	6	45988
2198·0	*1		45481				

IODINE (ABSORPTION).[1]

* Double. † Triple. ⊙ Coincident with a solar line.

Wave-length	Intensity and Character	Oscillation Frequency	Wave-length	Intensity and Character	Oscillation Frequency
6316·51	4	15826·8	6301·16†	3 (bracketed with next line)	15865·3
6314·66	2	15831·4	6300·51†		15866·9
6314·26	2	15832·4	6300·22	3	13867·7
6313·90	2	15833·3	6300·00	3	15868·2
6313·53	3	15834·2	6299·58*	5⊙	15869·3
6313·18	3	15835·1	6298·94*	5⊙	15870·9
6312·76	3	15836·2	6298·29	6	15872·5
6312·23*	3	15837·5	6297·76*	5	15873·9
6311·59*	3	15839·1	6297·15*	3	15875·4
6311·11	3	15840·3	6296·82	3	15876·2
6310·74	4	15841·2	6296·31	5⊙	15877·5
6310·36	3	15842·2	6295·91	3	15878·5
6310·08	4	15842·9	6295·31	5	15880·0
6309·38	4	15844·6	6294·75	6	15881·5
6308·67†	4	15846·4	6294·25	6	15882·7
6308·05	4	15848·0	6293·72*	4	15884·1
6307·73	2	15848·8	6293·29	3⊙	15885·1
6307·38	3	15849·7	6292·91*	4	15886·1
6307·00	3	15850·6	6292·45*	5	15887·3
6306·64	3s	15851·5	6291·94	6	15888·6
6306·13*	3	15852·8	6291·46	6	15889·8
6305·69	3	15853·9	6290·98*	4	15891·0
6305·38	3	15854·7	6290·62	3⊙	15891·9
6304·83	3	15856·1	6290·23*	3	15892·9
6304·21	4	15857·6	6289·83	6	15893·9
6303·57	3	15859·2	6289·34	4	15895·1
6302·34	3⊙	15862·3	6288·90*	4	15896·2
6301·50	2	15864·4	6288·63	2	15896·9

[1] Hasselberg, *Mémoires de l'Académie des Sciences de St. Pétersbourg*, vii[e] série, vol. xxxvi. (1888).

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency	Wave-length	Intensity and Character	Oscillation Frequency
6288·21*	4	15898·0	6263·94	3	15959·6
6287·82	3	15899·0	6263·58	2	15960·5
6287·36	4	15900·1	6263·23	3	15961·4
6286·83*	4	15901·4	6262·91	2	15962·2
6286·37	3	15902·6	6262·59	4	15963·0
6285·98	4	15903·6	6261·95	3	15964·6
6285·61	3	15904·6	6261·42*	5	15966·0
6285·40	3	15905·1	6260·73*	4	15967·8
6285·08	4	15905·9	6260·37	3	15968·7
6284·68	4	15906·9	6260·10	5	15969·4
6284·19	4	15908·2	6259·42	3	15971·1
6283·86	3	15909·0	6258·80	4	15972·7
6283·45	3	15910·0	6258·22	4	15974·2
6282·98	4s	15911·2	6257·68	4	15975·5
6282·59	3	15912·2	6257·08	3	15977·1
6282·28	3⊙	15913·0	6256·42	4	15978·8
6281·90*	4	15914·0	6255·86	4	15980·2
6281·14	5	15915·9	6255·35	4	15981·5
6280·41	5 } ⊙	15917·7	6254·74*	5	15983·1
6280·01	3 }	15918·7	6254·26	4	15984·3
6279·75	5	15919·4	6253·89	3	15985·2
6279·46	5⊙	15920·1	6253·61	3	15986·0
6279·13	3	15921·0	6253·07	6	15987·3
6278·79	5	15921·8	6252·96*	6	15987·6
6278·25	2	15923·2	6252·59	4	15988·6
6277·88	5⊙	15924·1	6252·12	5	15989·8
6277·36	5 } ⊙	15925·5	6251·85	3	15990·5
6277·00	5 }	15926·4	6251·58	3	15991·1
6276·36	4	15928·0	6251·33	2	15991·8
6275·56*	4	15930·0	6251·06	4	15992·5
6275·11*	2	15931·2	6250·62	3	15993·6
6274·73	3	15932·1	6250·12*	5	15994·9
6274·35	2	15933·1	6249·63	3	15996·1
6274·01	5	15934·0	6249·15	5	15997·4
6273·67	2	15934·8	6248·66	3	15998·6
6273·24	4	15935·9	6248·19	5	15999·8
6272·85	3	15936·9	6247·60	2	16001·3
6272·42	4	15938·0	6247·27	3	16002·2
			6246·94	3	16003·0
Group 6272–6234			6246·41	3	16004·4
			6246·05	4	16005·3
6272·42	4	15938·0	6245·59	4	16006·5
6271·75	4	15939·7	6245·21	3 } band	16007·4
6271·06*	3	15941·5	6244·78	4 }	16008·5
6270·22	2	15943·6	6244·48	3 } band	16009·3
6269·81	2	15944·6	6243·96	4 }	16010·7
6269·54	4	15945·3	6243·62	4	16011·5
6269·07	2	15946·5	6243·24	4	16012·5
6268·78	4	15947·3	6242·89	2	16013·4
6268·38	2	15948·3	6242·57	4	16014·2
6268·06	4	15949·1	6242·23	3	16015·1
6267·64	2	15950·2	6241·88	4	16016·0
6267·30	4	15951·0	6241·55	3	16016·8
6266·69*	3	15952·6	6241·12	5	16017·9
6266·04	4	15954·2	6240·89	4⊙	16018·5
6265·28	5	15956·2	6240·60	4	16019·3
6264·60	3	15957·9	6240·26	3	16020·1
6264·30	2	15958·7	6239·89	3	16021·1

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency	Wave-length	Intensity and Character	Oscillation Frequency
6239·41	3	16022·3	6219·36	2	16074·0
6239·09	2	16023·1	6219·15	2	16074·5
6238·56	3	16024·5	6218·81	3	16075·4
6238·24	3	16025·3	6218·50	4	16076·2
6237·72*	6	16026·7	6218·21	4	16077·1
6237·28*	2	16027·8	6217·86	3	16077·9
6236·95	4s	16028·6	6217·58	3	16078·6
6236·56	2	16029·6	6217·12*	5	16079·8
6236·21	4	16030·5	6216·83	2	16080·5
6235·88	4	16031·4	6216·57	4	16081·2
6235·46	4	16032·5	6216·23	2	16082·1
6235·03	4	16033·6	6215·93*	5	16082·9
6234·77	3	16034·2	6215·27	4	16084·6
6234·43	4	16035·1	6214·92	4	16085·5
6234·23	4	16035·6	6214·64	4	16086·2
6233·93	4	16036·4	6214·26*	3	16087·2
			6213·83	4	16088·3
			6213·40	4	16089·4
Group 6234–6191			6212·95*	5	16090·6
			6212·41	6	16092·0
6233·93	4	16036·4	6212·11	2	16092·7
6233·69	2	16037·0	6211·87	5	16093·4
6233·38	2	16037·8	6211·29*	5	16094·9
6232·58	3	16039·9	6210·86*	4	16095·9
6232·14	3	16041·0	6210·53	2	16096·8
6231·79	3	16041·9	6210·18*	6	16097·7
6231·41	2	16042·9	6209·64	4	16099·1
6230·81	2	16044·4	6209·40	2	16099·8
6230·51	4	16045·2	6209·17	5s	16100·4
6230·20	4	16046·0	6208·81	3	16101·3
6229·68	6	16047·3	6208·55	3 } band	16102·0
6229·31	2	16048·3	6208·06	4	16103·2
6228·95	4	16049·2	6207·56	4	16104·5
6228·55	2	16050·2	6207·13*	5	16105·6
6228·24 }	5	16051·0	6206·69	4	16106·8
6227·95 }		16051·8	6206·16†	5	16108·2
6227·43*	3	16053·1	6205·66	4	16109·5
6226·85	3	16054·6	6205·24	5	16110·5
6226·51	2	16055·5	6204·79*	3 } band	16111·7
6226·21*	2	16056·3	6204·28*	4	16113·0
6225·76	3	16057·4	6203·88	4	16114·1
6225·28	2	16058·7	6203·48*	4	16115·1
6224·98	3	16059·5	6203·08	3	16116·2
6224·58*	2	16060·5	6202·88	3	16116·7
6224·31	3	16061·2	6202·59	4	16117·4
6223·94	3	16062·1	6202·21	3 } band	16118·4
6223·64	4	16062·9	6201·74	3	16119·6
6223·17 }	4	16064·1	6201·44	4	16120·4
6222·93 }		16064·7	6201·03	4	16121·5
6222·73	2	16065·3	6200·28*	4	16123·4
6222·41*	4	16066·1	6199·89	3	16124·4
6222·04	2	16067·0	6199·48	4	16125·5
6221·71	4	16067·9	6199·13	2	16126·4
6221·10 }	4	16069·5	6198·86	4	16127·1
6220·89 }		16070·0	6198·52	2	16128·0
6220·54	4	16070·9	6198·19	4	16128·9
6220·27	3	16071·6	6197·86	3	16129·7
6219·97	3	16072·4	6197·57	4	16130·5

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency	Wave-length	Intensity and Character	Oscillation Frequency
6197·28 }	4	16131·2	6177·94	4	16181·7
6196·62 }		16133·0	6177·60 }	4	16182·6
6196·32	4	16133·7	6176·93 }		16184·4
6196·05	2	16134·4	6176·62	2	16185·2
6195·79	4	16135·1	6176·31	3	16186·0
6195·53	3	16135·8	6175·98	2	16186·9
6195·28	3	16136·4	6175·65	4s⊙	16187·7
6195·04	2	16137·1	6175·37	3	16188·5
6194·75	4	16137·8	6175·02	3	16189·4
6194·57	4	16138·3	6174·67	2	16190·3
6194·26*	4	16139·1	6174·40	2	16191·0
6193·84	4	16140·2	6174·09	4	16191·8
6193·46	4	16141·2	6173·60*	5	16193·1
6192·48	4	16143·7	6173 00*	5	16194·7
6192·18	2	16144·5	6172·58	3	16195·8
6191·87	6	16145·3	6172·34	3	16196·4
6191·46	4	16146·4	6172·00	4	16197·3
6191·21	2	16147·0	6171·74	4	16198·0
6190·97*	5	16147·7	6171·39	2	16198·9
			6171·17	2	16199·5
Group 6191	–6149		6170·60	2	16201·0
			6170·17*	3	16202·1
6190·97	5	16147·7	6168·93	3	16205·4
6190·60	2	16148·6	6168·66	3	16206·1
6190·21	3	16149·7	6168·36	3	16206·9
6189·79	2	16150·8	6167·94*	4	16208·0
6189·46	4	16151·6	6167·44*	4	16209·3
6188·97	3	16152·9	6167·03	4	16210·4
6188·64	3	16153·7	6166·45	3	16211·9
6188·25	4	16154·8	6166·03*	2	16213·0
6187·86	4	16155·8	6165·63*	3	16214·0
6187·47	3	16156·8	6165·31	4	16214·9
6187·09	3	16157·8	6164·92*	4	16215·9
6186·68	4	16158·9	6164·45*	4	16217·1
6186·32	3	16159·8	6163·61	4	16219·4
6185·98	3	16160·7	6162·92	3	16221·2
6185·62	2	16161·7	6162·13	4	16223·3
6185·23	4	16162·7	6161·59†	4	16224·7
6184·88	2	16163·7	6160·79	3	16226·8
6184·50	4	16164·6	6160·41	3	16227·8
6184·13	3 } band	16165·6	6160·11	3	16228·6
6183·79	4 }	16166·4	6159·78	2	16229·4
6183·45	3 } band	16167·3	6159·42	3	16230·4
6183·05	4 }	16168·4	6159·20	2	16231·0
6182·70	2	16169·3	6158·92	3	16231·7
6182·33	3	16170·3	6158·58	3	16232·6
6181·96	3	16171·2	6158·32	2	16233·3
6181·60	2	16172·2	6158·05	5⊙	16234·0
6181·22	4	16173·2	6157·71	5	16234·9
6180·89	3	16174·0	6157·16*	5	16236·3
6180·59	4s⊙	16174·8	6156·77	3	16237·4
6180·23	3	16175·7	6156·44	4	16238·2
6179·92	4	16176·6	6156·12	2	16239·1
6179·52	4	16177·6	6155·85	2	16239·8
6179·24	4	16178·3	6155·47	4⊙	16240·8
6178·86	4	16179·3	6155·16	3	16241·6
6178·57	4	16180·1	6154·80	2	16242·6
6178·21	4	16181·0	6154·53	4	16243·3

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
6154·33	3	16243·8
6154·06	3	16244·5
6153·76	5	16245·3
6153·49	5	16246·0
6153·08*	6	16247·1
6152·57	3	16248·4
6152·18	4s	16249·5
6151·44	4	16251·5
6151·01*	5	16252·6
6150·58	5	16253·7
6150·20*	4	16254·7
6149·83	4	16255·7
6149·48	6	16256·6
6149·08	4	16257·7
Group 6149–6111		
6149·08	4	16257·7
6148·75	3	16258·6
6148·10*	4	16260·3
6147·61*	3	16261·6
6147·19	3	16262·7
6146·94	2	16263·4
6146·70	2	16264·0
6146·46	3	16264·6
6146·20	2	16265·3
6145·96	2	16265·9
6145·65	3	16266·8
6145·24	3	16267·9
6144·92*	3	16268·7
6144·49	3	16269·8
6144·15	3	16270·7
6143·80	2	16271·7
6143·46	4	16272·6
6142·77	4	16274·4
6142·34	3	16275·3
6141·62	3	16277·4
6141·30	3	16278·3
6140·96	3	16279·2
6140·64	3	16280·0
6140·27	3	16281·0
6139·93	2	16281·9
6139·55	3	16282·9
6139·08	3	16284·2
6138·77	3	16285·0
6137·53	3	16288·3
6136·57	3	16290·8
6136·21	3	16291·8
6135·86 }	4	16292·7
6135·62 }		16293·3
6135·29	3	16294·2
6134·98	3	16295·0
6134·64	3	16296·0
6134·35	2	16296·7
6134·00	3	16297·7
6133·70	3	16298·5
6133·33	3	16299·4

Wave-length	Intensity and Character	Oscillation Frequency
6133·09	2	16300·1
6132·79	3	16300·9
6132·48	2	16301·7
6132·20	3	16302·4
6131·89	3	16303·3
6131·63	3	16304·0
6131·35	3	16304·7
6131·05	2	16305·5
6130·75	2	16306·3
6130·45	2	16307·1
6130·10	4	16308·0
6129·85	2	16308·7
6129·60	2	16309·4
6129·34	2	16310·0
6129·07	4	16310·8
6128·77	2	16311·6
6128·52	2	16312·2
6128·21 }	4	16313·0
6127·98 }		16313·7
6127·65 }	3	16314·5
6127·46 }		16315·0
6127·17 }	4	16315·8
6126·95 }		16316·4
6126·63	3	16317·3
6126·17*	4	16318·5
6125·74*	3	16319·6
6125·26*	5	16320·9
6124·81*	4	16322·1
6124·35† }	3s	16323·3
6123·79† }		16324·8
6123·42	3s	16325·8
6123·14	3	16326·6
6122·89	3	16327·2
6122·27	3	16328·9
6122·00	3	16329·6
6121·76	3	16330·2
6121·51*	5	16330·9
6121·07*	4	16332·1
6120·73 }	4 band	16333·0
6120·30 }		16334·1
6119·90	4	16335·2
6119·51*	4	16336·2
6119·30	2	16336·8
6119·02	5	16337·5
6118·63	4	16338·6
6118·24*	4	16339·6
6118·00	3	16340·3
6117·63	3	16341·3
6117·34	3	16342·0
6117·00	3	16342·9
6116·75	2	16343·6
6116·50	4⊙	16344·3
6116·02*	4	16345·6
6115·56	3	16346·5
6115·29*	5	16347·5
6114·93 }	4	16348·5
6114·40 }		16349·9
6114·00	3	16351·0

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
6113·61	4	16352·0
6113·31 }	4	16352·8
6112·81 }		16354·1
6112·41	3	16355·2
6112·04	5	16356·2
6111·67	3	16357·2
6111·25*	6	16358·3
Group 6111–6069		
6111·25*	6	16358·3
6110·85	2	16359·4
6110·49	4	16360·4
6110·13	2	16361·3
6109·70*	5	16362·5
6109·30	2	16363·6
6108·87	6	16364·7
6108·20*	3	16366·5
6107·80	2	16367·6
6107·45	3	16368·5
6107·08	2	16369·5
6106·71	4	16370·5
6106·35	3n	16371·5
6106·00	3	16372·4
6105·60	3	16373·5
6105·20	3	16374·5
6104·92	3	16375·3
6104·56	5	16376·3
6104·25	5	16377·1
6103·86	4	16378·1
6102·78	4	16381·0
6102·12	4	16382·8
6101·76	3	16383·8
6101·44	4s	16384·6
6101·17	2	16385·3
6101·00	2	16385·8
6100·72	2	16386·6
6100·43	3 } band	16387·3
6100·10	5 }	16388·2
6099·43	3	16390·0
6099·02	3	16391·1
6098·74	3	16391·9
6098·44	2	16392·7
6098·08	3	16393·6
6097·81	2	16394·4
6097·48	4	16395·3
6096·86	4⊙	16396·9
6096·52	2	16397·8
6096·24	4	16398·6
6096·00	4	16399·2
6095·62	3	16400·3
6095·35	3	16401·0
6095·00	4	16401·9
6094·74	2	16402·6
6094·43	3	16403·5
6094·14	3	16404·2
6093·81	3	16405·1
6093·52	3	16405·9
6093·13 }	4	16407·0
6092·97 }		16407·4
6092·70	2	16408·1
6092·39	4	16409·0
6092·03	4	16409·9
6091·79	2	16410·6
6091·52	3	16411·3
6091·16	3	16412·3
6090·80	2	16413·2
6090·48	2⊙	16414·1
6090·13	3	16415·0
6089·61	3	16416·4
6089·36	2	16417·1
6089·14	2	16417·7
6088·89	2	16418·4
6088·61	5	16419·1
6088·35	5	16419·8
6087·95*	3	16420·9
6087·44*	5	16422·3
6086·91*	3	16423·7
6086·48*	5	16424·9
6085·93*	3	16426·4
6085·52	5⊙	16427·5
6085·00	4	16428·9
6084·51	5	16430·2
6084·06	3	16431·4
6083·85	3	16432·0
6083·55*	5	16432·8
6083·16	3	16433·8
6082·64	4	16435·2
6082·39	4	16435·9
6081·70	4	16437·8
6081·33*	5 } band	16438·8
6080·92	5 }	16439·9
6080·46	4	16441·2
6080·03	4	16442·3
6079·67	4	16443·3
6079·35	3⊙	16444·2
6078·87*	5	16445·5
6078·51	3	16446·4
6078·14	3	16447·4
6077·75 }	4 band	16448·5
6077·39 }		16449·5
6077·10	4	16450·3
6076·69	4	16451·4
6076·40	4	16452·2
6076·12	3	16452·9
6075·79	4	16453·8
6075·49	4	16454·6
6075·18	4	16455·2
6074·80	3	16456·5
6074·22*	5	16458·1
6073·71	4	16459·4
6073·34	4	16460·4
6073·01	3	16461·3
6072·66*	3	16462·3
6072·27 } †	5	16463·3
6071·69 }	5	16464·9

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
6071·46	3	16465·5
6071·08	3 } band	16466·6
6070·71	6 } band	16467·6
6070·43	3 } band	16468·3
6069·95	4	16469·6
6069·67	3	16470·4
6069·31	5	16471·4
Group 6069–6031		
6069·31	5	16471·4
6068·95	3	16472·3
6068·60*	3	16473·3
6068·19	2	16474·4
6067·80	3	16475·5
6067·49	2	16476·3
6067·11*	3	16477·3
6066·71	3	16478·4
6066·31*	4	16479·5
6065·61	5	16481·4
6065·28	2	16482·4
6064·92*	3	16483·3
6064·56	3	16484·3
6064·20*	3	16485·2
6063·87	2	16486·1
6063·49	6	16487·2
6063·16	2	16488·1
6062·77*	3	16489·1
6062·46	4s	16490·0
6062·11	4s	16490·9
6061·44	4	16492·7
6061·11	2	16493·6
6060·75	4	16494·6
6060·45	2	16495·4
6060·11	4	16496·4
6059·80	2	16497·2
6059·42	5	16498·2
6059·15	2	16499·0
6058·81	3	16499·9
6058·50	3	16500·7
6058·17	4	16501·6
6057·83	2	16502·6
6057·48	5	16503·5
6057·23	4	16504·2
6056·85	4	16505·2
6056·57	2	16506·0
6056·29	5⊙	16506·8
6055·95	2	16507·7
6055·62	4	16508·6
6055·38	3	16509·2
6055·05	3	16510·1
6054·77	2	16510·9
6054·41	5	16511·9
6054·21	2	16512·4
6053·89	4	16513·3
6053·61	3	16514·1
6053·28	5	16515·0
6052·71 }	4	16516·5
6052·50 }		16517·1
6052·11	4	16518·2
6051·52	6	16519·8
6050·98	4	16521·2
6050·48	5	16522·6
6050·29	2	16523·1
6050·00	? }	16523·9
6049·30*	4 }	16525·8
6048·93	4	16526·8
6048·75	4	16527·3
6048·42	3	16528·2
6048·23	3	16528·8
6047·82*	6	16529·9
6047·33*	4	16531·2
6046·87*	6	16532·5
6046·39*	4	16533·8
6045·94*	6	16535·0
6045·45*	4	16536·4
6045·00*	5	16537·6
6044·53*	4	16538·9
6044·13*	5	16540·0
6043·66*	4	16541·3
6043·25*	5	16542·4
6042·81	6	16543·6
6042·43	4⊙	16544·6
6042·00	3	16545·8
6041·61	4	16546·9
6041·17	3	16548·1
6040·79	4	16549·1
6040·40	3	16550·2
6040·07	4	16551·1
6039·74	4	16552·0
6039·39	3	16553·0
6039·02	5	16554·0
6038·63	4	16555·1
6038·33	5	16555·9
6038·02	5	16556·7
6037·73	3	16557·5
6037·39	5	16558·4
6036·98	3	16559·6
6036·79	3	16560·1
6036·48	5	16560·9
6036·19	3	16561·7
6035·82*	6	16562·8
6035·36*	3	16564·0
6034·83*	6	16565·5
6034·45	3	16566·5
6034·13	5	16567·4
6033·89	3	16568·1
6033·61	3	16568·8
6033·40	6 } band	16569·4
6033·05	6 } band	16570·4
6032·87	2	16570·9
6032·57	5	16571·7
6032·34	4	16572·3
6031·92 }	6 band	16573·5
6031·58 }		16574·4
6031·33	2	16575·1
6030·99	6	16576·0

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
Group 6031–5992		
6030·99	6	16576·0
6030·60	2	16577·1
6030·20*	3	16578·2
6029·47	4	16580·2
6028·68	4	16582·4
6028·00	4	16584·2
6027·64	2	16585·2
6027·31	4⊙	16586·1
6026·54	4	16588·3
6025·85	3	16590·2
6025·67	2	16590·6
6025·46	2	16591·2
6025·16	3	16592·0
6024·38*	6⊙	16594·2
6023·78	4	16595·9
6023·44	2	16596·8
6023·11	3	16597·7
6022·85	2	16598·4
6022·44	4	16599·5
6021·80	3	16601·3
6021·56	3	16602·0
6021·12	4s	16603·2
6020·85	2	16603·9
6020·38*	6⊙	16605·2
6019·86	4	16606·7
6019·62	3	16607·3
6019·28	4	16608·5
6019·00	3	16609·0
6018·62	4	16610·1
6018·37	8	16610·8
6018·04	4	16611·7
6017·77	4	16612·4
6017·34	4br	16613·6
6016·59	3 } band	16615·7
6016·28	3 } band	16616·5
6015·99	3 } band	16617·3
6015·70	2	16618·1
6015·45	4	16618·8
6015·05 }	3	16619·9
6014·83 }		16620·5
6014·47 }	4	16621·5
6014·20 }		16622·3
6014·04	2	16622·7
6013·48	2	16624·3
6013·09	2	16625·3
6012·56	4	16626·8
6012·00*	2	16628·4
6011·59	3s	16629·5
6011·34	2	16630·2
6010·93	2	16631·3
6010·69	3	16632·0
6010·50	2	16632·5
6010·28	2	16633·1
6009·88	4	16634·3
6009·40*	3	16635·6
6008·85*	6	16637·1

Wave-length	Intensity and Character	Oscillation Frequency
6008·55	? } band	16637·9
6007·94	4 } band	16639·6
6007·52	4⊙	16640·8
6007·04	5	16642·1
6006·58	4	16643·4
6006·14	5	16644·6
6005·74	4	16645·7
6005·28	5	16647·0
6004·86	4	16648·2
6004·42	5	16649·4
6004·03	4	16650·5
6003·62	5	16651·6
6003·26	4⊙	16652·5
6002·81*	4	16653·8
6002·44	4	16654·9
6002·06 }	5	16655·9
6001·61 }		16657·2
6001·28	2	16658·1
6000·96	4	16659·0
6000·57	3	16660·1
6000·25	4	16660·9
5999·93	3	16661·8
5999·61	3	16662·7
5999·31	4	16663·6
5998·97	3	16664·5
5998·63	4	16665·4
5998·38	4	16666·1
5997·77	4	16667·8
5997·47	2	16668·7
5997·23	2	16669·3
5997·00	4	16669·9
5996·74	3	16670·7
5996·52	2	16671·3
5996·12*	5	16672·4
5995·77	2	16673·4
5995·40	5	16674·4
5995·00	3	16675·5
5994·65 }	6	16676·5
5994·42 }		16677·1
5993·89	6n	16678·6
5993·03	6	16681·0
5992·60	2	16682·2
5992·30	4	16683·0
Group 5992–5955		
5992·30	4	16683·0
5992·00	2	16683·9
5991·67	4	16684·8
5990·98	4	16686·7
5990·58	2	16687·8
5990·21	4	16688·9
5989·87	2	16689·8
5989·50	5	16690·8
5988·80	5	16692·8
5988·12	4	16694·7
5987·76	2	16695·7
5987·42	4⊙	16696·6

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5986·73	5	16697·6
5986·01	4	16700·6
5985·70	2	16701·4
5985·34*	5	16702·4
5984·71*	4	16704·2
5984·07	4⊙	16706·0
5983·71	2	16707·0
5983·38	4	16707·9
5982·74*	5	16709·7
5982·08*	4	16711·5
5981·65 }	4	16712·7
5981·40 }		16713·4
5981·13	2	16714·2
5980·81	4	16715·1
5980·24	4	16716·7
5979·64*	4	16718·3
5979·29	2	16719·3
5979·00	4	16720·1
5978·73	2	16720·9
5978·41	4	16721·8
5977·87	5	16723·3
5977·24	5	16725·1
5976·75*	5	16726·5
5976·11	5	16728·2
5975·60	6	16729·7
5975·05	5	16731·2
5974·53	5	16732·7
5974·00	5	16734·2
5973·49	4	16735·6
5973·00*	4	16737·0
5972·46	5	16738·5
5971·95	4	16739·9
5971·45	5	16741·3
5970·97	4	16742·6
5970·49	5	16744·0
5970·00	4	16745·4
5969·58	5	16746·5
5969·11	4	16747·9
5968·71	5	16749·0
5968·22	4	16750·4
5967·83	5	16751·5
5967·37	4	16752·7
5966·97	5	16753·9
5966·52	4	16755·1
5966·16	5⊙	16756·1
5965·71	4	16757·4
5965·35	5	16758·4
5964·96	4	16759·5
5964·54	4	16760·7
5964·17	2	16761·7
5963·78	4	16762·8
5963·49	3	16763·6
5963·17	3	16764·5
5962·82	4	16765·5
5962·47	3	16766·5
5962·10	5	16767·6
5961·88	5	16768·2
5961·58	3	16769·0

Wave-length	Intensity and Character	Oscillation Frequency
5961·14	4	16770·2
5960·92	2	16770·9
5960·63	4	16771·7
5960·33	4	16772·5
5959·90	4	16773·7
5959·56	4	16774·7
5959·40	2	16775·1
5959·17	3	16775·8
5958·80	5 }	16776·8
5958·37	5 }	16778·0
5958·00	4	16779·1
5957·63	2	16780·1
5957·26	4	16781·2
5956·55*	5	16783·2
5956·11	2	16784·4
5955·78	5s	16785·3
5955·42	4	16786·3
5954·98	4	16787·6
Group 5955	–5917	
5954·98	4	16787·6
5954·32*	4	16789·4
5953·52	3⊙	16791·7
5952·79	3	16793·8
5952·40	2	16794·9
5952·09	4	16795·7
5951·41	4	16797·7
5950·73	4	16799·6
5950·07	5	16801·4
5949·36	5	16802·4
5948·83 }	6	16804·8
5948·62 }		16805·5
5948·14 }	5	16806·9
5947·94 }		16807·4
5947·35	4	16809·1
5946·75	4	16810·8
5946·08	5	16812·7
5945·42	4	16814·6
5945·14	2	16815·4
5944·79	4	16816·4
5944·18	5	16818·1
5943·87	2	16819·0
5943·57	4	16819·8
5943·29	2	16820·6
5942·92	5	16821·6
5942·32	4	16823·3
5942·04	2	16824·1
5941·75	4	16825·0
5941·21*	5	16826·5
5940·60	4	16828·2
5940·36	2	16828·9
5940·05	4	16829·8
5939·44	5	16831·5
5938·89	4	16833·1
5938·36	5	16834·6
5937·84	3	16836·1
5937·61	3	16836·7

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5937·29	4	16837·6
5936·79	3	16839·0
5936·59	3	16839·6
5936·23	3	16840·6
5935·72	4	16842·1
5935·30	3	16843·3
5934·82*	4	16844·6
5934·55	2	16845·4
5934·30	2	16846·1
5934·07	2	16846·8
5933·90	4	16847·2
5933·35	2	16848·8
5933·00	5	16849·8
5932·53	4	16851·0
5932·11	5	16852·3
5931·45	4	16853·6
5931·24	5	16854·8
5930·80	4	16856·0
5930·40*	5	16857·2
5929·95	4⊙	16858·5
5929·56	5	16859·6
5929·12	3	16860·8
5928·72	4	16862·0
5928·35	3	16863·0
5927·96*	4	16864·1
5927·63	2	16865·1
5927·25	4	16866·1
5927·00	4	16866·8
5926·67	3	16867·8
5926·27	4	16868·9
5925·98	3	16869·7
5925·68	4	16870·6
5925·35	4	16871·5
5925·03	3	16872·4
5924·59*	6	16873·7
5923·98	5	16875·4
5923·67	5	16876·3
5923·40	3	16877·1
5923·08	4s	16878·0
5922·86	4s	16878·6
5922·53 }	6 band	16879·6
5922·04 }		16881·0
5921·77 }	7 band	16881·7
5921·24 }		16883·2
5921·00 }	7 band	16883·9
5920·58 }		16885·1
5920·34	3	16885·8
5920·00	6	16886·8
5919·75	6	16887·5
5919·36	7	16888·6
5919·11	7	16889·3
5918·64	5	16890·7
5918·31	5	16891·6
5917·92	5	16892·7
5917·55	5	16893·8
Group 5917–5881		
5917·55	**5**	**16893·8**

Wave-length	Intensity and Character	Oscillation Frequency
5917·17	2	16894·9
5916·87	2	16895·7
5916·50	3	16896·8
5916·13	2	16897·8
5915·78	3	16898·8
5915·42	3	16899·9
5915·05	3	16900·9
5914·60	3	16902·2
5914·30	3	16903·0
5914·04	2	16903·8
5913·71	2	16904·7
5913·30	4	16905·9
5913·11	2	16906·5
5912·60 }	4	16907·9
5912·31 }		16908·7
5911·95	3	16909·8
5911·70	3	16910·5
5911·48	4	16911·1
5911·22	2	16911·9
5910·57 }	5	16913·7
5910·32 }		16914·4
5909·89	4	16915·7
5909·62	2	16916·4
5909·31	5	16917·3
5908·65	4	16919·2
5908·33	2	16920·1
5908·03	4	16921·0
5907·42	5	16922·7
5906·87	4	16924·3
5906·22*	5	16926·2
5905·62	5	16927·9
5905·05	4	16929·6
5904·50*	5	16931·1
5904·02	3	16932·5
5903·97	3	16932·7
5903·45	3	16934·1
5903·24	3	16934·7
5902·96	4	16935·5
5902·71	4	16936·3
5902·44	3	16937·0
5902·17	3	16937·8
5901·84	4	16938·8
5901·56	3	16939·6
5901·31	3	16940·3
5900·91*	5	16941·4
5900·42	5	16942·8
5899·95	5	16944·2
5899·41	5	16945·7
5898·98	5	16947·0
5898·46	5	16948·5
5898·00	5	16949·8
5897·50	5	16951·2
5897·05*	5	16952·5
5896·71	2	16953·5
5896·02	2	16955·5
5895·76	2	16956·2
5895·50	4	16957·0
5895·07	4	16958·2

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency	Wave-length	Intensity and Character	Oscillation Frequency
5894·65	4	16959·4	5875·24	2	17015·4
5894·22	4	16960·6	5874·86	4	17016·5
5893·83	4	16961·8	5874·47	2	17017·6
5893·43	4	16962·9	5874·22	4	17018·3
5893·07	3	16964·0	5873·61	5	17020·1
5892·77	3	16964·8	5873·28	2	17021·1
5892·40	3	16965·9	5872·94	5	17022·1
5892·08	4	16966·8	5872·39	4	17023·7
5891·72	3	16967·8	5872·02	2	17024·7
5891·35	4	16968·9	5871·74	5	17025·6
5890·97	4	16970·0	5871·35	2	17026·7
5890·15	3	16972·4	5871·16	4	17027·2
5889·86	3	16973·2	5870·57	5	17029·0
5889·54	3	16974·1	5870·14	4	17030·2
5889·23	3	16975·0	5869·88	4	17031·0
5888·84*	4	16976·1	5869·58	3	17031·8
5888·48	3	16977·2	5869·23	3	17032·9
5888·13	4	16978·2	5868·95	2	17033·7
5887·83	4	16979·0	5868·67	3s	17034·5
5887·57	2	16979·8	5868·38	2	17035·3
5887·28	4s	16980·6	5868·05	4	17036·3
5886·95	3	16981·6	5867·77	2	17037·1
5886·75	2	16982·2	5867·49	3	17037·9
5886·45	4	16983·0	5867·23	2	17038·7
5886·13	2	16984·0	5866·91*	6	17039·6
5885·86	5	16984·7	5866·42	5	17041·0
5885·60	5	16985·5	5865·93	5	17042·4
5885·35	2	16986·2	5865·36	4	17044·1
5885·00	6	16987·2	5865·04	3	17045·0
5884·74	6	16988·0	5864·81	4	17045·7
5884·10	6	16989·8	5864·32	4 }	17047·1
5883·83	2	16990·6	5864·00	2 }	17048·1
5883·43	4	16991·7	5863·70	3 } band	17048·9
5882·77	5	16993·6	5863·44	2 }	17049·7
5882·23	3	16995·2	5863·22	4 }	17050·3
5881·91	4	16996·1	5862·69	4	17051·9
5881·71	2	16996·7	5862·26	4	17053·1
5881·42	2	16997·5	5861·76	4	17054·6
5881·17	5	16998·3	5861·33	5	17055·8
			5860·87	4 }	17057·2
Group 5881	–5846		5860·54	3 }	17058·1
			5860·27	3 }	17058·9
5881·17	5	16998·3	5859·85	6 }	17060·1
5880·53	5	17000·1	5859·40	3	17061·4
5880·02	2	17001·6	5859·00	5	17062·6
5879·73*	4	17002·4	5858·60	4	17063·8
5879·09	3	17004·3	5858·28	2	17064·7
5878·75	2	17005·3	5858·08	7	17065·3
5878·54	2	17005·9	5857·63	7	17066·6
5878·18	3	17006·9	5857·30	5	17067·6
5877·68	3	17008·4	5856·91	5	17068·7
5877·48	4	17008·9	5856·49*	6	17069·9
5876·91	3	17010·6	5856·04	4	17071·2
5876·69	3	17011·2	5855·69	4s	17072·2
5876·50	3	17011·8	5855·29*	4	17073·4
5876·18*	3	17012·7	5854·90	4	17074·5
5875·84	2	17013·7	5854·55	3	17075·6
5875·54	4	17014·5	5854·11	5	17076·8

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency	Wave-length	Intensity and Character	Oscillation Frequency
5853·78	3	17077·8	5834·79	2	17133·4
5853·53	4	17078·5	5834·49	4	17134·3
5853·13	4	17079·7	5834·24	4	17135·0
5852·92	3	17080·3	5833·87	4	17136·3
5852·17	3	17082·5	5833·32*	5	17137·7
5851·83	4	17083·5	5832·82*	5	17139·2
5851·56 }	5	17084·3	5832·28	4	17140·8
5851·30 }		17085·0	5831·59*	4	17142·8
5851·00	5	17085·9	5831·11	4s	17144·2
5850·76	5	17086·6	5830·56	4s	17145·8
5850·51 }		17087·3	5830·07	5	17147·3
5850·22 }	6	17088·2	5829·52*	5	17148·9
5849·93 }		17089·0	5828·97	4 } band	17150·5
5849·71	2	17089·7	5828·44	5 }	17152·1
5849·37	3	17090·7	5827·93*	5	17153·6
5849·00	2	17091·8	5827·51	4	17154·8
5848·57	7 ⊙	17093·0	5827·05	4	17156·2
5848·27	2	17093·9	5826·70	3	17157·2
5847·98 }	5 band	17094·7	5826·51	3	17157·7
5847·50 }		17096·1	5826·13	5	17158·9
5847·08	6	17097·4	5825·90	2	17159·5
5846·54	6	17098·9	5825·67	4	17160·2
5846·22	6	17099·9	5825·20	5	17161·6
5845·66*	4	17101·5	5824·68	4 } band	17163·1
			5824·25	5 }	17164·4
			5823·83	4	17165·6
Group 5846–5811			5823·40*	5	17166·9
5845·66*	4	17101·5	5823·00	3 } band	17168·1
5844·90	5	17103·7	5822·63	4 }	17169·2
5844·52	2	17104·9	5822·23	3	17170·1
5844·14	4	17106·0	5821·83	4	17171·5
5843·79	2	17107·0	5821·46	3	17172·6
5843·50	5s	17107·8	5821·07	4	17173·8
5842·74†	4	17110·1	5820·81	3	17174·5
5842·17	4	17111·7	5820·31	4	17176·0
5841·94	4	17112·4	5819·98	4	17177·0
5841·62	3	17113·4	5819·62	4	17178·1
5841·35	4s	17114·1	5819·28	4	17179·1
5841·00	3	17115·2	5818·95	3	17180·0
5840·65	4	17116·2	5818·54	4	17181·2
5840·40	2	17116·9	5818·33	2	17181·9
5840·06	5	17117·9	5817·91	4	17183·1
5839·83	4	17118·6	5817·69	4	17183·7
5839·48	5	17119·6	5817·40	4	17184·0
5839·24	4	17120·3	5817·05	4	17185·6
5838·86	4	17121·4	5816·78	3	17186·4
5838·66	5	17122·0	5816·47	3	17187·4
5838·24	5	17123·3	5816·23	3	17188·1
5838·00	4	17124·0	5816·02	3	17188·7
5837·52	4	17125·4	5815·76	3	17189·5
5837·23	2	17126·2	5815·40	6	17190·5
5836·89	4	17127·2	5815·03	4	17191·6
5836·62	2	17128·0	5814·70*	4	17192·6
5836·29	3	17129·0	5814·24*	4	17193·9
5836·04	3	17129·7	5813·90	5	17194·9
5835·66*	4	17130·7	5813·32	5	17196·7
5835·35	2	17131·8	5813·00	3	17197·6
5835·04	4s	17132·7	5812·66	6	17198·6

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5812·36	2	17199·5
5811·91	4	17200·8
5811·65	6	17201·6
Group 5811–5778		
5811·65	6	17201·6
5811·33	2	17202·5
5811·03	3	17203·5
5810·77	3	17204·2
5810·30	4	17205·6
5809·63	4	17207·6
5809·24	4	17208·7
5808·89	2	17209·8
5808·51	4	17210·9
5808·26	4	17211·6
5807·92	4	17212·6
5807·66	4	17213·4
5807·32	3	17214·4
5807·05	4⊙	17215·2
5806·69	2	17216·3
5806·50	4	17216·9
5806·24	3	17217·6
5805·86 }	6⊙	17218·8
5805·63 }		17219·4
5805·27 }	4	17220·5
5805·05 }		17221·2
5804·78	2	17222·0
5804·53 }	5	17222·7
5804·31 }		17223·3
5803·98 }	4s	17224·3
5803·77 }		17225·0
5803·42	4	17226·0
5803·12	4s	17226·9
5802·72	3	17228·1
5802·45	3	17228·9
5802·08 }	5s	17230·0
5801·88 }		17230·6
5801·47*	3	17231·8
5801·02	3	17233·1
5800·77	3	17233·9
5800·38	4	17235·0
5800·11	3	17235·8
5799·83	3	17236·7
5799·63	4	17237·3
5799·22	5	17238·5
5798·69 }	6	17240·1
5798·45 }		17240·8
5798·14 }	6	17241·7
5797·93 }		17242·3
5797·49*	5	17243·6
5796·97*	5	17245·2
5796·42	3	17246·8
5796·04	3	17247·9
5795·72	3	17248·9
5795·37	3 } band	17249·9
5794·87*	4 }	17251·4
5794·41*	4	17252·8
5793·96*	4	17254·1
5793·47	6	17255·6
5793·00	5	17257·0
5792·52*	4	17258·4
5792·02*	4	17259·9
5791·58	4	17261·2
5790·65	3	17264·0
5790·33	3	17264·9
5789·85	4	17266·4
5789·41	4	17267·7
5789·00	4	17268·9
5788·62*	3	17270·0
5787·78	2	17272·6
5787·44	4	17273·6
5787·17	4	17274·4
5786·78	4	17275·5
5786·44	4	17276·6
5786·03	5	17277·8
5785·71	4	17278·7
5785·36	4	17279·8
5785·06	5	17280·7
5784·75	3	17281·6
5784·46	3	17282·5
5784·24	3	17283·1
5783·85	3	17284·3
5783·42	4	17285·6
5783·00	3	17286·8
5782·43	4	17288·5
5781·93*	4	17290·0
5781·45*	4	17291·5
5781·02*	3	17292·7
5780·65	5	17293·8
5780·42*	4	17294·5
5780·09	5 } band	17295·5
5779·79	5 }	17296·4
5779·47	5 }	17297·4
5779·18	5 }	17298·3
5778·87	6	17299·2
5778·62	6	17299·9
5778·28	6	17300·9
Group 5778–5746		
5778·28	6	17300·9
5777·93	2	17302·0
5777·61*	4	17302·9
5777·21	2	17304·1
5776·89*	5	17305·1
5776·54	2	17306·2
5776·19	3	17307·2
5775·85	3	17308·2
5775·42	4	17309·5
5775·15	2	17310·3
5774·85	2	17311·2
5774·49	5	17312·3
5774·17	2	17313·3
5773·80	3	17314·4
5773·52	2	17315·2

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5773·14	3	17316·3
5772·84	2	17317·2
5772·52	4	17318·2
5772·26	4	17319·0
5771·93	4	17320·0
5771·63	3	17320·9
5771·24	3	17322·0
5771·02	4	17322·7
5770·67	4	17323·8
5770·34	2	17324·7
5770·04	2	17325·6
5769·75	4s } band	17326·5
5769·18	4s }	17328·2
5768·85	3	17329·2
5768·59	3	17330·0
5768·25	4s	17331·0
5767·90	2	17332·1
5767·63	2	17332·9
5767·38	4	17333·6
5767·12	4	17334·4
5766·81	2	17335·3
5766·48 }	4	17336·3
5766·30 }		17336·9
5765·96	4	17337·9
5765·74	2	17338·6
5765·47 }	5	17339·4
5765·19 }		17340·2
5764·85	3	17341·3
5764·63	4	17341·9
5764·35	2	17342·8
5764·08	3	17343·6
5763·68	4	17344·8
5763·07	4s	17346·6
5762·80	3	17347·4
5762·53	3⊙	17348·2
5762·33	2	17348·8
5762·00	3	17349·8
5761·69	5	17350·8
5761·18*	5	17352·3
5760·72*	5	17353·7
5760·26*	4	17355·1
5759·88	4	17356·2
5759·66	2	17356·9
5759·41	3	17357·6
5759·18	3	17358·3
5758·90	4	17359·2
5758·57	3	17360·2
5758·28	3	17361·0
5757·96*	3	17362·0
5757·55*	4	17363·2
5757·29	2	17364·0
5756·94	3s⊙	17365·1
5756·53	3n	17366·3
5755·98*	4	17368·0
5755·51	3	17369·4
5755·09	5 } band	17370·7
5754·47	5 }	17372·5
5754·13	4	17373·6

Wave-length	Intensity and Character	Oscillation Frequency
5753·75	5	17374·7
5753·36	4 } band	17375·9
5752·72	3 }	17377·8
5752·51	2	17378·4
5752·21	4⊙	17379·4
5751·87	4	17380·4
5751·49	3	17381·5
5751·11	3	17382·7
5750·68	5	17384·0
5750·33	4	17385·0
5749·97*	4	17386·1
5749·61	3	17387·2
5749·20	3	17388·5
5748·86	4	17389·5
5748·53	4⊙	17390·5
5748·13	4⊙	17391·7
5747·75	5	17392·8
5747·42	5	17393·8
5747·14	2	17394·7
5746·83	5	17395·6
5746·52	2	17396·6
5746·21	6	17397·5
5745·92	6	17398·4
Group 5746–5715		
5745·92	6	17398·4
5745·65	2	17399·2
5745·39	2	17400·0
5745·04	3	17401·0
5744·66	4	17402·2
5744·41	3	17402·9
5744·02*	3	17404·1
5743·69	3	17405·1
5743·36	4	17406·1
5743·00	4	17407·2
5742·64	3	17408·3
5742·28 }	5⊙	17409·4
5742·10 }		17410·0
5741·75	3	17411·0
5741·41	2	17412·0
5741·07	5	17413·1
5740·79	5 } band	17413·9
5740·43	2 }	17415·0
5740·14	3 }	17415·9
5739·78	4	17417·0
5739·55	2	17417·7
5739·18	3	17418·8
5738·94	2	17419·5
5738·64	3	17420·5
5738·30	3	17421·5
5738·00	2	17422·4
5737·71	3	17423·3
5737·33	4	17424·4
5737·09	4	17425·2
5736·76	3	17426·2
5736·45	2	17427·1
5736·26	4	17427·7

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency	Wave-length	Intensity and Character	Oscillation Frequency
5735·88	2	17428·8	Group 5715–5684		
5735·64	3	17429·6			
5735·43	3	17430·2	5714·92	6	17492·8
5735·05	4	17431·3	5714·42	3	17494·3
5734·78	4	17432·2	5714·11	4	17495·2
5734·50	2	17433·0	5713·73	3	17496·4
5734·24	2	17433·8	5713·45	3	17497·3
5734·00	2	17434·5	5713·17	3	17498·1
5733·71	2	17435·4	5712·89	3	17499·0
5733·42	3	17436·3	5712·24	6	17501·0
5733·21	3	17436·9	5711·84	2	17502·2
5732·95	3	17437·7	5711·09	4	17504·5
5732·64	2	17438·7	5710·75	3	17505·5
5732·27	3	17439·8	5710·29*	5	17506·9
5731·95	5s ⊙	17440·8	5709·25	4	17510·1
5731·66	5s	17441·6	5708·38*	6	17512·8
5731·40	2	17442·4	5707·92	3	17514·2
5731·13	4	17443·3	5707·33†	5	17516·0
5730·75*	4	17444·4	5706·52	4	17518·5
5730·27*	4	17445·9	5706·17	3	17519·6
5729·92	2	17447·0	5705·85	3	17520·6
5729·67	3	17447·8	5705·52	3	17521·6
5729·46	2	17448·4	5705·24	2	17522·4
5729·24	2	17449·0	5704·87	5	17523·6
5728·84*	3	17450·3	5704·57	2	17524·5
5728·44*	5	17451·5	5704·23	2	17525·5
5727·90*	5	17453·1	5703·89	5s	17526·6
5727·46	3 }	17454·5	5703·60	2	17527·5
5727·24	3 }	17455·1	5703·27	4	17528·5
5726·97	3	17456·0	5702·79	5	17530·0
5726·70	3	17456·8	5702·57	3	17530·6
5726·25*	5	17458·2	5702·26	3 } band	17531·6
5725·81*	3	17459·5	5702·04	3 } band	17532·3
5725·29*	5	17461·1	5701·19	4 } band	17534·9
5724·64	5 } band	17463·1	5700·61*	5	17536·7
5724·30	2 } band	17464·1	5700·16	2	17538·0
5724·10	2 } band	17464·7	5699·60	5	17539·8
5723·75	5 } band	17465·8	5699·19	2	17541·0
5723·17*	4	17467·4	5698·97	2	17541·7
5722·77	4	17468·8	5698·70	6⊙	17542·5
5722·37	5 } band	17470·0	5698·28*	2	17543·8
5721·91	5 } band	17471·4	5697·84	6s	17545·2
5721·47	3	17472·7	5697·33*	2	17546·7
5721·09*	4	17473·9	5696·92*	4	17548·0
5720·60*	6	17475·4	5696·43	4	17549·5
5719·96	5	17477·3	5696·07*	5	17550·6
5719·40 }	5	17479·1	5695·61	4	17552·0
5718·98 }	5	17480·3	5695·26*	5	17553·1
5718·55	5	17481·7	5694·82	3	17554·5
5718·18	5⊙	17482·8	5694·57	3	17555·3
5717·76	5n	17484·1	5694·29	3	17556·1
5717·46	4n	17485·0	5694·00	4⊙ } band	17557·0
5717·04	5	17486·3	5693·59	4 } band	17558·3
5716·67	3	17487·4	5693·05†	6	17560·0
5716·31*	5	17488·5	5692·53	3	17561·6
5715·85	4	17489·9	5692·21	5	17562·6
5715·45*	6	17491·1	5691·50	5	17564·7
5714·92*	6	17492·8	5691·14	2	17565·9

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5690·81	5s ⊙	17566·9
5690·51	3	17567·8
5690·09*	5	17569·1
5689·67	3	17570·4
5689·20*	5	17571·8
5688·88	2	17572·8
5688·09	3	17575·3
5687·85	3	17576·0
5687·58	3	17576·8
5687·12*	5	17578·3
5686·41*	4	17580·5
5686·02	4	17581·7
5685·63	5	17582·9
5685·09†	6	17584·5
5684·54	6s	17586·2
Group 5684–5655		
5684·54	6	17586·2
5684·25	3	17587·1
5683·76	4	17588·7
5683·08*	6	17590·8
5682·35	4	17593·0
5681·80	4	17594 7
5681·18*	3	17596·6
5680·52	5	17598·7
5680·10	3	17600·0
5679·78	4	17601·0
5679·39 }	5⊙	17602·2
5679·16 }		17602·9
5678·59	6n	17604·7
5678·02	5	17606·4
5677·62	3	17607·7
5677·30	3	17608·7
5676·82*	6	17610·2
5676·22	3	17612·0
5675·77*	5	17613·4
5675·04*	4	17615·7
5674·58	3	17617·1
5674·00	4	17618·9
5673·57	3	17620·2
5673·23	3s	17621·3
5672·96	3s	17622·1
5672·42	5s	17623·8
5671·95	3	17625·3
5671·43	5s	17626·9
5670·44	4	17630·0
5669·87	4	17631·7
5669·45*	5	17633·0
5669·00	4s	17634·4
5668·47	4n	17636·1
5668·11	4s	17637·2
5667·61	4	17638·8
5667·22	4	17640·0
5666·63*	5	17641·8
5666·34	3	17642·7
5665·90	5	17644·1
5665·50	3	17645·3
5665·02	5	17646·9
5664·74	3	17647·7
5664·38	5	17648·8
5663·94	3	17650·2
5663·61	3	17651·2
5663·38	5	17651·9
5662·58	3	17654·4
5662·22	3s	17655·6
5661·89	4s	17656·6
5661·54	3	17657·7
5661·16 }	5	17658·8
5660·91 }		17659·6
5660·66	2	17660·4
5660·38	4	17661·3
5660·04	3	17662·3
5659·76	4	17663·2
5659·46	2	17664·2
5658·98	6⊙	17665·7
5658·17*	5	17668·2
5657·82	2	17669·3
5657·48	4	17670·3
5656·71	4	17672·8
5656·42	3	17673·7
5656·10	5	17674·7
5655·05	4	17678·0
5654·71	4	17679·0
Group 5655–5626		
5654·71	4	17679·0
5654·14	4	17680·8
5653·77	2	17682·0
5653·43	5	17683·0
5653·15	2	17683·9
5652·74	5	17685·2
5652·15	5	17687·0
5651·79	2	17688·1
5651·41*	4	17689·3
5650·86	4⊙	17691·1
5650·35*	5	17692·7
5649·94	2	17693·9
5649·61*	6s	17695·0
5649·02	5	17696·8
5648·44	5	17698·6
5648·15	3	17699·5
5647·68*	7	17701·0
5647·21	3s	17702·5
5646·72	6	17704·0
5646·43	2	17704·9
5646·14	6 } band	17705·8
5645·82	3 } band	17706·9
5645·50	4 } band	17707·9
5645·01	5	17709·4
5644·77	2	17710·1
5644·49	3	17711·0
5644·14	3	17712·1
5643·83	3	17713·1
5643·63	2	17713·7

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5643·41	4	17714·4
5642·90	5s	17716·0
5642·40	5s	17717·6
5642·15	2	17718·4
5641·91	4	17719·1
5641·33	2	17720·9
5640·90	6	17722·3
5640·48	4	17723·6
5640·00	6	17725·1
5639·53	2	17726·6
5639·15	6	17727·8
5638·64	4 } band	17729·4
5638·23	6 }	17730·7
5637·79	2	17732·1
5637·36*	6⊙	17733·4
5636·87	4	17735·0
5636·51	4	17736·1
5636·19	3 }	17737·1
5635·97	4 } band	17737·8
5635·71	4 }	17738·6
5635·35	3	17739·7
5634·94	3	17741·0
5634·66	4	17741·9
5634·29	4 } band	17743·1
5633·62	4 }	17745·2
5633·26	2	17746·3
5632·95	5	17747·3
5632·63	4	17748·3
5632·24 }	5	17749·5
5632·00 }		17750·3
5631·70*	5	17751·2
5631·39	5	17752·2
5631·11	5	17753·1
5630·63*	5	17754·6
5630·34	2	17755·5
5630·04	4	17756·5
5629·82	2	17757·2
5629·64	4	17757·7
5629·31	5	17758·8
5628·90† }	6	17760·1
5628·35† }		17761·8
5627·97	6	17763·0
5627·59	2	17764·2
5627·19	6	17765·5
5626·50*	6	17767·6
Group 5626–5599		
5626·50	6	17767·6
5626·00	4	17769·2
5625·67	2	17770·3
5625·30	4	17771·4
5624·95	3	17772·5
5624·18	5	17775·0
5623·84	2	17776·0
5623·50	5	17777·1
5623·15	3	17778·2
5622·85	3	17779·2
5622·56	2	17780·1
5622·23	4	17781·1
5621·94	3	17782·1
5621·68	3	17782·9
5621·36	4	17783·9
5621·00	3	17785·0
5620·59 }	7	17786·3
5620·33 }		17787·2
5619·84	5	17788·7
5619·59	2	17789·5
5619·32*	4 }	17790·4
5618·76*	4 }	17792·1
5618·38	3 }	17793·3
5618·17	2 }	17794·0
5617·81 }	5	17795·1
5617·54 }		17796·0
5617·36	2	17796·6
5617·06	5	17797·5
5616·50	6	17799·3
5616·20	2	17800·2
5615·05*	5⊙	17803·9
5614·53	6	17805·5
5614·04	4	17807·1
5613·77	4	17807·9
5613·50	4	17808·8
5613·23	4	17809·7
5613·03	4	17810·3
5612·79	4	17811·1
5612·58	5	17811·7
5612·11	4	17813·2
5611·91	4	17813·8
5611·64	3	17814·7
5611·28	5	17815·8
5610·81	5	17817·3
5610·41	3	17818·6
5610·19	4	17819·3
5609·93	4	17820·1
5609·57	4	17821·3
5609·07*	5	17822·9
5608·74	3	17823·9
5608·36	5	17825·1
5607·94	5	17826·4
5607·67	4	17827·3
5607·35*	5	17828·3
5606·82	5	17830·0
5606·56	4	17830·8
5606·21	4	17832·0
5605·75*	5	17833·4
5605·50	3	17834·2
5605·20	4	17835·2
5604·93	4	17836·0
5604·65	4	17836·9
5604·31	4	17838·0
5604·00	4	17839·0
5603·79	5	17839·6
5603·47	2	17840·7
5602·98	6	17842·2
5602·73	4	17843·0

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5602·44	4	17843·9
5602·24	5	17844·6
5602·06	2	17845·2
5601·81	6	17846·0
5601·30	3	17847·6
5600·95 }	5	17848·7
5600·72 }		17849·4
5600·37*	4	17850·5
5599·97	4s	17851·8
5599·61*	4	17853·0
5599·14	6	17854·5
Group 5599–5587		
5599·14	6	17854·5
5598·37	5	17856·9
5597·94	3	17858·3
5597·61*	5	17859·3
5597·14	4	17860·8
5596·79	4	17862·0
5596·40	3	17863·2
5596·05	5	17864·3
5595·71	3	17865·4
5595·34	4	17866·6
5594·98	4	17867·7
5594·32	2	17869·9
5594·00	5	17870·9
5593·70	2	17871·8
5593·40	4	17872·8
5593·12	4	17873·7
5592·82	4	17874·6
5592·29	5	17876·3
5592·00	2	17877·3
5591·75	5s	17878·0
5591·51	2	17878·8
5591·23	4	17879·7
5591·04	5	17880·3
5590·82	2	17881·0
5590·56	2	17881·9
5590·03	5	17883·5
5589·57	4	17885·0
5589·26	4	17886·0
5588·98	6⊙	17886·9
5588·49	3	17888·5
5588·19	4	17889·4
5587·91	4	17890·4
5587·56	5	16891·5
Group 5587–5560		
5587·56	5	17891·5
5586·55	3	17894·7
5586·31	4	17895·5
5586·02	4	17896·4
5585·64	5	17897·6
5585·35	2	17898·6
5585·10	6	17899·4
5584·74	2	17900·5
5584·45	4	17801·4
5584·18	3	17902·3
5583·84	4	17903·4
5583·59	2	17904·2
5583·36	3	17904·9
5583·16	2	17905·6
5582·91	2	17906·4
5582·64	5	17907·2
5582·06	4	17909·1
5581·81	4	17909·9
5581·42	4	17911·2
5581·07	5	17912·3
5580·90	5	17912·8
5580·60	2	17913·8
5580·30	4s	17914·8
5579·64	5	17916·9
5579·21	5	17918·3
5578·59	3	17920·2
5578·29	5	17921·2
5578·01	5	17922·1
5577·63 }	6	17923·3
5577·42 }		17924·0
5577·12	4	17925·0
5576·79	2	17926·0
5576·29	2	17927·6
5576·03	4	17928·5
5575·80	2	17929·2
5575·58	4	17929·9
5575·35	2	17930·7
5575·04	5	17931·7
5574·60	4	17933·1
5574·11	6	17934·6
5573·64	4	17936·2
5573·41	5	17936·9
5572·71	6	17939·1
5572·28	4	17940·5
5571·87	4	17941·9
5571·44	4	17943·2
5571·01	4	17944·6
5570·61	4	17945·9
5570·21	4	17947·2
5569·82*	5	17948·5
5569·46	5	17949·6
5569·06	4	17950·9
5568·74	4	17951·9
5568·32	4	17953·3
5567·97	5	17954·4
5567·66	5⊙	17955·4
5567·27	4	17956·7
5566·93	2	17957·8
5566·57	4	17958·9
5566·29	3	17959·8
5565·69	4	17961·8
5565·38	3	17962·8
5565·10	5	17963·7
5564·81	4	17964·6
5564·52 }	5	17965·5
5564·29 }		17966·3
5563·75	5	17968·0

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5563·50	4	17968·8
5563·30	3	17969·5
5563·06 }	5⊙	17970·3
5562·85 }		17970·9
5562·61	2	17971·7
5562·33*	5s	17972·6
5561·92	3	17973·9
5561·58	4 }	17975·0
5561·20	2 }	17976·3
5560·96	4 }	17977·0
5560·70	2 }	17977·9
5560·44	6 }	17978·7
5560·25	6 }	17979·3
5559·95	5 }	17980·3
5559·57	4 }	17981·5
Group 5560–5533		
5559·57	4	17981·5
5559·03	5	17983·3
5558·61	3	17984·6
5558·34	5	17985·5
5557·77	4	17987·4
5557·17*	6	17989·3
5556·87	2	17990·3
5556·54	4	17991·3
5556·04*	5	17992·9
5555·72	2	17994·0
5555·05	2	17996·2
5554·82	4	17996·9
5554·57	4	17997·7
5554·22	4⊙	17998·8
5553·89 }	3	17999·9
5553·61 }	6	18000·8
5553·07†	4	18002·6
5552·60	5	18004·1
5552·28	2	18005·2
5551·98	5	18006·1
5551·72	2	18007·0
5551·45	4	18007·9
5551·22	2	18008·6
5550·91	5	18009·6
5550·36	5	18011·4
5550·11	2	18012·2
5549·83	4	18013·1
5549·40	6	18014·5
5548·98	? } band	18015·9
5548·36	5 }	18017·9
5547·92	5 } band	18019·3
5547·68	2 }	18020·1
5547·41	4s }	18021·0
5546·96	6 }	18022·4
5546·50	5 }	18023·9
5546·07	4 }	18025·3
5545·57	6	18026·9
5545·35	2	18027·7
5545·11	3	18028·4
5544·76	5	18029·6

Wave-length	Intensity and Character	Oscillation Frequency
5544·33	4 }	18031·0
5543·92	5 }	18032·3
5543·14	5	18034·8
5542·72	3	18036·2
5542·37	6	18037·4
5542·00	2	18038·6
5541·61	2	18039·8
5541·29	4	18040·9
5540·91	6	18042·1
5540·54	3	18043·3
5540·22	4s	18044·3
5539·90	3	18045·4
5539·57	5	18046·5
5539·27	4	18047·4
5538·96	5	18048·4
5538·65	4	18049·5
5538·39	3	18050·3
5538·07	4s	18051·3
5537·79	3	18052·3
5537·55	3	18053·0
5537·26	3	18054·0
5537·01	3	18054·8
5536·80	5	18055·5
5536·59	5	18056·2
5536·34	2	18057·0
5536·09	5	18057·8
5535·69	2	18059·1
5535·41 }	5⊙	18060·0
5535·15 }		18060·9
5534·79*	4 }	18062·0
5534·33	2 }	18063·5
5533·93	4 }	18064·9
5533·68	2 }	18065·7
5533·37	6 }	18066·7
5533·20 }	4 }	18067·2
5532·85 }		18068·4
Group 5533–5507		
5532·85	4	18068·4
5532·40	4	18069·8
5532·10	3	18070·8
5531·75	4 } band	18072·0
5531·10	6 }	18074·1
5530·56	5	18075·9
5530·22	4	18077·0
5529·88	5	18078·1
5529·39	5	18079·7
5529·23	2	18080·2
5528·37	2	18083·0
5528·14	4	18083·8
5527·58*	6	18085·6
5526·97*	5	18087·6
5526·64	2	18088·7
5526·38*	6	18089·5
5525·98	4	18090·8
5525·38 }	5	18092·8
5525·18 }		18093·5

Iodine (Absorption)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5524·86	3	18094·5
5524·57	2	18095·4
5524·28	5	18096·4
5524·02	2	18097·2
5523·75	5	18098·1
5523·49	2	18099·0
5523·22	5	18099·9
5522·96	2	18100·7
5522·25	6 } band	18103·0
5521·79*	6 }	18104·6
5521·34	6	18106·0
5521·08	2	18106·9
5520·81	3	18107·8
5520·33*	6	18109·3
5519·86	4	18110·9
5519·46	5	18112·2
5519·00	4	18113·7
5518·62	5	18114·9
5518·37	2	18115·8
5518·14	4s } band	18116·5
5517·73	4 }	18117·9
5517·30*	4	18119·3
5516·93	4	18120·5
5516·55	5n	18121·8
5516·15	4	18123·1
5515·81*	5	18124·2
5515·44	4	18125·4
5515·03	4	18126·8
5514·35*	4	18129·0
5514·01	3	18130·1
5513·67	3	18131·2
5513·35	4	18132·3
5513·08	3	18133·2
5512·76	4⊙	18134·2
5512·45	3⊙	18135·2
5512·12	3	18136·3
5511·86	2	18137·2
5511·61	5 } band	18138·0
5511·30	3 }	18139·0
5511·01	4	18140·0
5510·77	4	18140·8
5510·52	4	18141·6
5510·29	5	18142·4
5510·11	5⊙	18143·0
5509·91	2	18143·6
5509·67	3	18144·4
5509·44	3	18145·2
5509·17	3	18146·1
5508·95	5	18146·8
5508·69	5	18147·6
5508·51	2	18148·2
5508·26	4	18149·0
5508·03	4	18149·8
5507·84	3	18150·4
5507·63	3	18151·1
5507·37	3	18152·0
5506·84	4	18153·7

Wave-length	Intensity and Character	Oscillation Frequency
Group 5507–5482		
5506·84	4	18153·7
5506·49	4	18154·9
5506·28	5	18155·6
5505·70	5	18157·5
5505·19	6	18159·2
5504·95	6	18160·0
5504·51	3 } band	18161·4
5504·26	3 }	18162·2
5503·86	5 }	18163·6
5503·42	5 } band	18165·0
5503·00	2 }	18166·4
5502·72*	4 }	18167·3
5502·43	2	18168·3
5502·13*	3	18169·3
5501·66	3	18170·8
5501·44	3	18171·5
5501·22	3	18172·3
5501·06	3	18172·8
5500·78	3	18173·7
5500·43*	6	18174·9
5499·94*	4	18176·5
5499·68	2	18177·3
5499·40*	3	18178·3
5499·14	2	18179·1
5498·80	4	18180·3
5498·32	7	18181·8
5497·81*	7	18183·5
5497·51† }	6	18184·5
5497·15† }		18185·7
5496·88	2	18186·6
5496·67	3	18187·3
5496·36	6	18188·3
5495·88	4	18189·9
5495·60	2	18190·8
5495·34*	4	18191·7
5495·05† }		18192·7
5494·76† }		18193·6
5494·52	4	18194·4
5494·33	4	18195·0
5494·00*	5	18196·1
5493·58*	5	18197·5
5493·24	3	18198·7
5493·05	3	18199·3
5492·75	4	18200·3
5492·42	2	18201·4
5492·25	2	18201·9
5491·93	4 } band	18203·0
5491·75	3 }	18203·6
5491·52	3 }	18204·4
5491·09	5 }	18205·8
5490·78 }	3 band	18206·8
5490·37* }	6	18208·2
5490·00	3	18209·4
5489·67	6	18210·5
5489·29	3	18211·7
5488·95*	6	18212·9

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5488·55	3	18214·2
5488·14†	4	18215·6
5487·62	4	18217·3
5487·32	2	18218·3
5487·01	4	18219·3
5486·74	3	18220·2
5486·46	3	18221·1
5486·20	3	18222·0
5485·93	3 } band	18222·9
5485·27	5 } band	18225·1
5484·93	3	18226·2
5484·70	3	18227·0
5484·48	3	18227·7
5484·22	3	18228·6
5483·95	4	18229·5
5483·27	4	18231·7
5483·00 }	6 band	18232·6
5482·11* }		18235·6
5481·65	5⊙	18237·2
Group 5482–5457		
5481·65	5	18237·2
5481·38	2	18238·1
5481·05*	3	18239·2
5480·77	3	18240·1
5480·29*	5	18241·7
5479·88	4	18243·0
5479·53	4	18244·2
5479·19	4	18245·3
5478·95	4	18246·1
5478·59	2	18247·3
5478·39	2	18248·0
5478·09	4	18249·0
5477·79	2	18250·0
5477·47	4	18251·1
5476·30	4	18255·0
5476·03	4	18255·9
5475·56	4	18257·4
5475·21	4	18258·6
5475·01	3	18259·3
5474·67	4	18260·4
5474·47	3	18261·1
5473·93	5	18262·9
5473·55*	6	18264·1
5473·12 }	6 band	18265·6
5472·67 }		18267·1
5472·43	3	18267·9
5472·24	3	18268·5
5471·85	4s	18269·8
5471·52*	4	18270·9
5471·07*	5	18272·4
5470·75	4	18273·5
5470·48	3	18274·4
5470·15	3	18275·5
5469·96	2	18276·1
5469·77	2	18276·7
5469·45	3	18277·8
5469·15*	4	18278·8
5468·78*	5	18280·1
5468·38*	6	18281·4
5467·95*	2	18282·8
5467·50*	4	18284·3
5467·12	2	18285·6
5466·76	7	18286·8
5466·41	2	18288·0
5465·96	4	18289·5
5465·72	4	18290·3
5465·32*	5	18291·6
5464·82	2	18293·3
5464·51	5	18294·3
5464·24	2	18295·2
5463·90	5	18296·4
5462·90	5	18299·7
5462·58	5	18300·8
5462·25	4	18301·9
5461·98	4	18302·8
5461·71	3	18303·7
5461·50	5	18304·4
5461·18	3	18305·5
5460·76	4	18306·9
5460·44	3	18308·0
5460·12 }	5	18309·0
5459·81 }		18310·1
5459·54	3	18311·0
5459·22	4	18312·1
5458·85	5	18313·3
5458·56	5	18314·3
5458·25	3	18315·3
5457·90 }	6	18316·5
5457·08 }		18319·2
Group 5457–5434		
5457·13	5	18319·1
5456·79	2	18320·2
5456·44	3	18321·4
5456·15	2	18322·4
5455·47	2	18324·6
5455·16	4	18325·7
5454·90	4	18326·6
5454·50*	3	18327·9
5454·09	3	18329·3
5453·78	3	18330·3
5453·48	2	18331·3
5453·14	3	18332·5
5452·90	2	18333·3
5452·66	3	18334·1
5452·29	3	18335·3
5452·03	2	18336·2
5451·79	2	18337·0
5451·51	5	18338·0
5451·21	5	18339·0
5450·78	3	18340·4
5450·46	3	18341·5
5450·12	3	18342·6

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5449·55*	5	18344·5
5449·04*	5	18346·3
5448·74	2	18347·3
5448·45	2	18348·3
5448·20	2	18349·1
5447·94	2	18350·0
5447·76	2	18350·6
5447·46	5	18351·6
5446·26	3	18355·6
5445·89	3	18356·9
5445·61	3	18357·8
5445·28*	5	18359·0
5444·83*	4	18360·5
5444·43	3	18361·8
5444·09	4	18363·0
5443·72	3	18364·2
5443·30 }	4 } 6 lines	18365·6
5441·87 }	3 }	18370·5
5441·54 }	3 } 4 lines	18371·6
5440·51* }	5 }	18375·1
5440·07	2	18376·5
5439·67*	5	18377·9
5439·39	5	18378·8
5439·08	4	18379·9
5438·72	5	18381·1
5438·43	6	18382·1
5438·08	3	18383·3
5437·79	3	18384·2
5437·43	4	18385·5
5437·01	3	18386·9
5436·52*	5	18388·5
5436·05	5	18390·1
5435·72	5	18391·2
5435·43	4	18392·2
5435·21	4	18393·0
5434·42	5	18395·6
5434·03*	6	18397·0
5433·58	5	18398·5

Group 5434–5411

Wave-length	Intensity and Character	Oscillation Frequency
5433·58	5	18398·5
5432·94	3	18400·6
5432·68	2	18401·5
5432·37	3 }	18402·6
5432·09	2 } band	18403·5
5431·82	3 }	18404·4
5431·46 } †	3	18405·7
5431·20 }	2	18406·5
5430·71*	6	18408·2
5430·37	2	18409·4
5429·51	2	18412·3
5429·24	2	18413·2
5428·91	5	18414·3
5428·25*	4	18416·5
5427·79*	3	18418·1
5427·24*	4	18420·0
5426·79*	4	18421·5
5426·40	3	18422·8
5426·13	2	18423·7
5425·76*	6	18425·0
5425·46	2	18426·0
5424·84†	5⊙	18428·1
5424·30	5	18429·9
5423·95*	4	18431·1
5423·33*	5	18433·2
5423·05 }	4	18434·2
5422·26 }		18436·9
5422·02	4	18437·7
5421·64	4	18439·0
5421·19*	5	18440·5
5420·90	4	18441·5
5420·31	4	18443·5
5419·78†	6	18445·3
5418·85	6	18448·5
5418·44	4	18449·9
5418·11	4	18451·0
5417·75	4	18452·2
5417·45	4	18453·2
5416·99*	6	18454·8
5416·57	2	18456·2
5416·16*	5	18457·6
5415·11	2	18461·2
5414·66	2	18462·7
5414·28	6	18464·0
5413·71	2	18466·0
5413·40	5	18467·0
5412·91	3	18468·7
5412·31*	6	18470·8
5411·66*	7	18473·0
5410·75	6 band	18476·1

Group 5411–5389

Wave-length	Intensity and Character	Oscillation Frequency
5410·75	6	18476·1
5410·40	2	18477·3
5409·79		18479·4
5409·47	3	18480·5
5409·16*	4	18481·5
5408·67*	2	18483·2
5408·19*	5	18484·9
5407·63*	4	18486·8
5407·12*	4	18488·5
5406·56*	4	18490·4
5405·91	3	18492·7
5405·38	2	18494·5
5404·96*	6	18495·9
5404·04*	6	18499·1
5403·47*	4	18501·0
5403·02*	4	18502·5
5402·51*	4	18504·3
5401·97*	5	18506·1
5401·53*	3	18507·7
5401·09*	5	18509·2
5400·57	3	18510·9
5400·21*	4	18512·2
5399·74	4	18513·8

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5399·39	2	18515·0
5399·06*	5s	18516·1
5398·21	4	18519·0
5397·85	2	18520·3
5396·75	4	18524·0
5396·35	5	18525·4
5396·09	5	18526·3
5395·67	4	18527·7
5395·44*	5	18528·5
5394·60*	4	18531·4
5394·12	4	18533·1
5393·91 }	4 } band	18533·8
5393·44 }	6 } band	18535·4
5392·70	5	18537·9
5392·09*	5	18540·0
5391·35*	5	18542·6
5390·85	6	18544·3
5390·21†	7s }	18546·5
5389·57	4 }	18548·7
5389·01*	8 }	18550·6
Group 5389–5367		
5389·01*	8	18550·6
5388·43	4	18552·6
5387·84*	4	18554·7
5387·21*	4	18556·8
5386·66	5	18558·7
5386·00*	4	18561·0
5385·50	4	18562·7
5385·00	5	18564·4
5384·36*	3	18566·6
5383·83	5	18568·5
5383·38	5	18570·0
5382·92	4	18571·6
5382·43*	4	18573·3
5381·90	6	18575·1
5381·37	3	18577·0
5380·93	6	18578·5
5380·35	4	18580·5
5379·94	5	18581·9
5379·53	5	18583·3
5378·99	3	18585·2
5378·58*	5	18586·6
5378·05*	6	18588·4
5377·32	6	18591·0
5376·98	5	18592·1
5376·55	5	18593·6
5376·13	5	18595·1
5375·85	5	18596·1
5375·20	6	18598·3
5374·75	2	18599·9
5374·38	6	18601·1
5373·73	4	18603·4
5373·38	4	18604·6
5373·11	4	18605·5
5372·78	2	18606·7
5372·43	4	18607·9
5372·17	2	18608·8
5371·47	2	18611·2
5371·03*	4	18612·8
5370·46*	5	18614·7
5369·74*	6	18617·2
5369·20	6	18619·1
5368·86	3	18620·2
5368·51	6	18621·5
5368·01	7	18623·2
5367·42	5	18625·3
Group 5367–5347		
5367·42	5	18625·3
5366·94	4	18626·9
5366·43	4	18628·7
5365·76	5⊙	18631·0
5364·76*	6	18634·5
5364·15	4	18636·6
5363·67	4	18638·3
5362·61	4	18642·0
5362·09	3	18643·8
5361·64*	5	18645·3
5361·05	5	18647·4
5360·64	4	18648·8
5360·19	5	18650·4
5359·70	3	18652·1
5359·45	3	18653·0
5359·22	3	18653·8
5358·81	6	18655·2
5358·36	3	18656·7
5357·91	6	18658·3
5357·50	2	18659·7
5357·09*	4	18661·2
5356·63	6	18662·8
5356·26	2	18664·1
5355·89	6	18665·3
5355·53	2	18666·6
5355·14	5	18668·0
5354·81	2	18669·1
5354·42	5	18670·5
5354·11	4	18671·6
5353·28*	6	18674·4
5352·81	3	18676·1
5352·46	5 }	18677·3
5352·23	4 }	18678·1
5351·90	4	18679·3
5351·64	4	18680·2
5351·37	4	18681·1
5351·10	4	18682·1
5350·87	2	18682·8
5350·56*	6	18683·9
5349·87	6⊙	18686·3
5349·28	4	18688·4
5348·70*	5s	18690·4
5348·42	2	18691·4
5348·06	6	18692·7
5347·35*	7	18695·1

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
Group 5347–5327		
5347·35*	7	18695·1
5346·79	3	18697·1
5346·24*	6	18699·0
5345·65*	4	18701·3
5345·17	4	18702·8
5344·71	5	18704·4
5344·04	5	18706·7
5343·56	4	18708·4
5343·12*	6	18709·9
5342·45*	5	18712·3
5342·01	4	18713·8
5341·43	6	18715·9
5340·93*	4	18717·6
5340·54	2	18719·0
5340·14*	6	18720·4
5339·62	3	18722·2
5339·37	3	18723·1
5339·11	3	18724·0
5338·67	4	18725·6
5338·24	4	18727·1
5337·84	4	18728·5
5337·45	3	18729·8
5337·09*	5⊙	18731·1
5336·56*	5 } band	18733·0
5336·24	3 } band	18734·1
5335·81	4	18735·6
5335·45	3	18736·9
5335·10	4	18738·1
5334·76	3	18739·3
5334·42	4	18740·5
5334·07	2	18741·7
5333·73	6	18742·9
5333·39	3	18744·1
5333·10	6⊙	18745·1
5332·73	2	18746·4
5332·41	3	18747·5
5332·15	2	18748·5
5331·76	4 } band	18749·8
5331·41	2 } band	18751·1
5330·97	6s	18752·6
5330·84	2	18753·1
5330·53	5 } band	18754·2
5330·18	4 } band	18755·4
5329·80	3	18756·7
5329·32*	6⊙	18758·4
5327·96	4	18763·2
5327·76	2	18763·9
5327·47	5	18764·9
Group 5327–5308		
5327·47	5	18764·9
5326·94	5	18766·8
5326·39	4	18768·7
5326·06	3	18769·9
5325·76	4	18770·9
5325·26	5	18772·7
5324·74	3	18774·5
5324·13	3	18776·7
5323·70	4	18778·2
5323·16	4	18780·1
5322·64	3	18781·9
5322·17*	5	18783·6
5321·68	4 } band	18785·3
5321·41	4 } band	18786·3
5321·15	4 } band	18787·2
5320·72	5	18788·7
5320·29	3	18790·2
5319·84	4	18791·8
5319·38*	5	18793·5
5318·94	3	18795·0
5318·55*	5	18796·4
5318·16	2	18797·8
5317·74*	4	18799·3
5317·37	3	18800·6
5316·55	4	18803·5
5316·18	2	18804·8
5315·79	4	18806·1
5315·44	2	18807·4
5315·13	4	18808·5
5314·78	2	18809·7
5314·49*	5	18810·7
5314·17	2	18811·9
5313·87*	5	18812·9
5313·55	2	18814·1
5313·28 }	5	18815·0
5313·02 }	5	18815·9
5312·55*	4	18817·6
5312·19	2	18818·9
5311·85	3	18820·1
5311·65	2	18820·8
5311·32*	4	18822·0
5310·89 } †	4	18823·4
5310·67 } †	4	18824·3
5310·40	2	18825·3
5310·08	4	18826·4
5309·75	2	18827·5
5309·43	3	18828·7
5309·23	2	18829·4
5308·93	5	18830·4
5308·36	5	18832·5
Group 5308–5291		
5308·36	5	18832·5
5307·88	3	18834·2
5307·28	4	18836·3
5306·76*	4	18838·1
5306·21	4	18840·1
5305·73	4 } band	18841·8
5305·14*	5 } band	18843·9
5304·62*	4	18845·8
5304·18	4	18847·3
5303·68*	5	18849·1

Iodine (Absorption)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5303·18	4	18850·9
5302·26	4	18854·2
5301·78	3	18855·9
5301·41	4	18857·2
5300·96*	4 } band	18858·8
5300·50	3 }	18860·4
5300·14	3 }	18861·7
5299·75	3 } band	18863·1
5299·31*	3 }	18864·6
5298·96	3 } band	18865·9
5298·62	4⊙ }	18867·1
5298·18	3	18868·7
5297·80*	4⊙	18870·0
5297·49	2	18871·1
5297·14	4⊙	18872·4
5296·82	3 } band	18873·5
5296·47	3 }	18874·8
5296·10	4	18876·1
5295·83	2	18877·0
5295·51	3	18878·2
5295·23	3	18879·2
5294·92	3	18880·3
5294·67	3	18881·2
5294·36 }	5	18882·3
5294·18 }		18882·9
5293·93	2	18883·8
5293·56	5	18885·1
5293·07	5	18886·9
5292·76	2	18888·0
5292·60	2	18888·6
5292·41 }	4	18889·2
5292·21 }		18889·9
5291·90	4	18891·1
5291·70	2	18891·8
5291·35	3	18893·0
5291·12	4	18893·8
5290·72	6	18895·3
Group 5291–5273		
5290·72	6	18895·3
5289·63	4	18899·1
5289·06	5	18901·2
5288·53*	3	18903·1
5287·97	4	18905·1
5287·45*	4	18906·9
5286·86*	3	18909·1
5286·43	4	18910·6
5285·92	4 }	18912·4
5285·15	3 } band	18915·2
5284·94	2 }	18915·9
5284·52	4	18917·4
5284·03	4⊙ } band	18919·2
5283·60	4 }	18920·7
5283·13	4	18922·4
5282·70	4	18923·9
5282·18*	5	18925·8
5281·89	2	18926·8
5281·53*	4	18928·1
5281·13	3	18929·6
5280·72	4	18931·0
5280·32	4	18932·5
5279·97	3	18933·7
5279·63	3	18934·9
5279·29	3	18936·2
5278·96	3	18937·3
5278·60	3	18938·6
5278·30	3	18939·7
5277·96	3	18940·9
5277·63	3	18942·1
5277·32	3	18943·2
5276·97 }	4 } band	18944·5
5276·78 }	4 }	18945·2
5275·60*	5	18949·4
5275·16	4⊙	18951·0
5274·77	2	18952·4
5274·34	4	18953·9
5273·98	3	18955·2
5273·15	4	18958·2
5272·75*	5	18959·6
Group 5273–5255		
5272·75*	5	18959·6
5272·30	2	18961·3
5272·05	2	18962·2
5271·64*	4	18963·6
5271·28	3	18964·9
5271·00	2	18965·9
5270·15	2	18969·0
5269·44	2	18971·6
5268·98	3 } band	18973·2
5268·60	5 }	18974·6
5268·22*	2	18976·0
5267·62*	3	18978·1
5267·27	3	18979·4
5266·38*	3 band	18982·6
5265·49	3⊙	18985·8
5265·09	3⊙	18987·3
5264·50*	4	18989·4
5263·61	5⊙	18992·6
5263·17	4	18994·2
5262·83	3	18995·4
5262·13	4	18997·9
5261·85	3	18998·9
5261·55	3	19000·0
5261·20	3	19001·3
5260·93	3	19002·3
5260·61	3	19003·4
5260·29	3	19004·6
5259·85*	4	19006·2
5259·37*	4	19007·9
5259·02	2	19009·2
5258·61	4	19010·6
5258·22	4	19012·1
5257·91	2	19013·2

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5257·40*	4	19015·0
5257·07	4	19016·2
5256·68	4	19017·6
5256·27	4	19019·1
5255·89	3	19020·5
5255·71	2	19021·1
5255·32	4⊙	19022·5
Group 5255–5240		
5255·32	4	19022·5
5254·80*	3	19024·4
5254·38	3	19025·9
5253·59	3	19028·8
5253·24*	4	19030·1
5252·85	3	19031·5
5252·58	2 } band	19032·5
5252·11*	4 } band	19034·2
5251·72	3 } band	19035·6
5251·42	2	19036·7
5251·01	5⊙	19038·2
5250·29*	2s	19040·8
5249·88	2	19042·2
5249·60	2	19043·3
5249·30	4 } band	19044·3
5248·92	4 } band	19045·7
5248·63	2	19046·8
5248·26	3	19048·1
5247·90	3⊙	19049·4
5247·57	2	19050·6
5247·27	3⊙	19051·7
5246·91	2	19053·0
5246·66	2	19053·9
5246·35	3	19055·1
5245·97	3	19056·4
5245·58	2	19057·9
5245·29	2	19058·9
5245·03	4	19059·8
5244·71	4	19061·0
5244·38	2	19062·2
5244·00	4⊙	19063·6
5243·69	4	19064·7
5243·11	3	19066·8
5242·51	3	19069·0
5242·23	2	19070·0
5241·76*	3	19071·7
5241·32	2	19073·3
5241·09	3	19074·2
5240·78	3	19075·3
5240·46	3	19076·5
5240·02†	5	19078·1
Group 5240–5224		
5240·02†	5	19078·1
5239·81	3	19078·8
5239·46	2	19080·1
5239·15	3	19081·2
5238·94	2	19082·0
5238·70	2	19082·9
5238·35*	3	19084·1
5237·93	2	19085·7
5237·64	3 } band	19086·7
5237·15	3 } band	19088·5
5236·90	2	19089·4
5236·51	4	19090·9
5236·19	4	19092·0
5235·71*	3	19093·8
5235·23*	2	19095·5
5234·82	3⊙	19097·0
5234·44	2	19098·4
5234·15	3	19099·5
5233·74	3	19101·0
5233·16	4	19103·1
5232·74	3	19104·6
5232·48	2	19105·6
5232·16	3	19106·8
5231·85	2	19107·9
5231·49	2	19109·2
5231·12	2	19110·6
5230·80	2	19111·7
5230·51	2	19112·8
5229·65	4	19115·9
5229·32	2	19117·1
5229·00	3	19118·3
5228·71	3	19119·4
5228·44	3	19120·3
5228·16	2	19121·4
5227·86	2	19122·5
5227·52	4	19123·7
5227·18	5	19125·0
5226·34*	5	19128·0
5225·84	3	19129·9
5225·38*	4	19131·5
5225·07	2	19132·7
5224·69	2	19134·1
5224·42	2	19135·0
5224·10*	5	19136·2
Group 5224–5209		
5224·10*	5 } band	19136·2
5223·54	4 } band	19138·3
5223·09*	2 } band	19139·9
5222·65	4	19141·5
5222·10	4	19143·5
5221·70	3	19145·0
5221·41	2	19146·1
5221·13*	4	19147·1
5220·48*	3	19149·5
5220·00	5	19151·2
5219·67	3	19152·5
5219·32	4	19153·7
5218·92	4	19155·2
5218·51	3	19156·7
5218·22	3	19157·8

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency
5217·80*	4	19159·3
5217·24	4	19161·4
5216·92	4 band	19162·6
5216·50	4	19164·1
5215·83	6	19166·6
5215·10	2 band	19169·2
5214·77	4	19170·4
5214·48	2	19171·5
5213·95*	4	19173·5
5213·48	2	19175·2
5213·22*	3	19176·1
5212·85	2	19177·5
5212·50	3	19178·8
5212·23	3 band	19179·8
5211·95	3	19180·8
5211·64	3	19182·0
5211·41	3	19182·8
5211·08*	3	19184·0
5210·55*	2	19186·0
5210·03	4	19187·9
5209·80	3	19188·7
5209 46*	6	19190·0
Group 5209–5195		
5209·46*	6	19190·0
5208·38	4	19194·0
5208·01*	4	19195·3
5207·57	4	19196·9
5206·93		19199·3
5206·58	4	19200·6
5205·97	3	19202·8
5205·64	3	19204·1
5205·22*	4	19205·6
5204·35	3	19208·8
5203·92	4	19210·4
5203·51	2	19211·9
5203·21	4	19213·0
5202·36	4	19216·2
5202·00	2	19217·5
5201·61	4	19218·9
5201·30	4	19220·1
5201·00	2	19221·2
5200·71	5	19222·3
5200·51	3	19223·0
5200·02	4	19224·8
5199·46	4	19226·9
5199·17	2	19228·0
5198·94	4	19228·8
5198·42	5	19230·8
5198·16	2	19231·7
5197·80*	4⊙	19233·1
5197·29*	3	19234·9
5196·92	3	19236·3
5196·63	4 band	19237·4
5196·31	3⊙	19238·6
5196·09	3	19239·4

Wave-length	Intensity and Character	Oscillation Frequency
5195·74	4⊙	19240·7
5195·22	4⊙	19242·6
Group 5195–5182		
5195·22	4	19242·6
5194·73*	4	19244·4
5194·28	2	19246·1
5194·00	4	19247·1
5193·67*	3	19248·3
5193·25*	5	19249·9
5192·68	5	19252·0
5192·30	4	19253·4
5191·35	5	19256·9
5190·94	3	19258·5
5190·54		19259·9
5190·10	4 band	19261·6
5189·75		19262·9
5189·35	5	19264·4
5188·64	4	19267·0
5188·18	5	19268·7
5187·84	3	19270·0
5187·44	5	19271·5
5187·24	3	19272·2
5186·88	3	19273·5
5186·56	4	19274·7
5186·24	4	19275·9
5185·94	2	19277·0
5185·69	3	19278·0
5185·40	2	19279·0
5185·06*	4	19280·3
5184·52	3	19282·3
5183·38	5	19286·5
5182·91	5	19288·3
5182·42	3	19290·1
5181·96*	6	19291·8
Group 5182–5168		
5181·96	6	19291·8
5181·70	2	19292·8
5181·44	3	19293·8
5180·91*	4	19295·7
5180·37*	3	19297·8
5179·96	4	19299·3
5179·41*	5	19301·3
5179·00	3	19302·9
5178·61	5	19304·3
5178·24	2	19305·7
5178·00	3	19306·6
5177·72	3	19307·6
5177·32	3	19309·1
5176·90	4	19310·7
5176·52	3	19312·1
5176·07	4	19313·8
5175·75	3	19315·0
5175·37	4	19316·4
5175·00	4	19317·8

IODINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency	Wave-length	Intensity and Character	Oscillation Frequency
5174·66	3	19319·0	5159·36	5⊙	19376·3
5174·38	3.	19320·1	5159·10	5	19377·3
5174·10	5	19321·1	5158·74	3	19378·7
5173·63	4	19322·9	5158·43	3	19379·8
5172·49	3	19327·1	5158·10	3	19381·1
5172·16	3	19328·4	5157·72	4	19382·5
5171·43*	4	19331·1	5157·42	2	19383·6
5171·13	2	19332·2	5156·98	5	19385·3
5170·80	4	19333·5	5156·61	3	19386·7
5170·32*	2	19335·2	5156·16*	5	19388·4
5169·95	2	19336·6			
5169·62	3	19337·9	Group 5156	–5145	
5168·65*	5	19341·5			
			5156·16*	5	19388·4
Group 5168	–5156		5155·66	3	19390·2
			5155·16*	4	19392·1
5168·65*	5	19341·5	5154·73	3	19393·7
5168·27	3	19342·9	5154·36	5	19395·1
5167·17*	3	19347·0	5153·83	4	19397·1
5166·85	3	19348·2	5153·53	4	19398·3
5166·43	3	19349·8	5153·01	4 ⎫	19400·2
5166·21	2	19350·6	5152·62	4 ⎬ band	19401·7
5165·87*	3	19351·9	5151·79	5 ⎭	19404·8
5165·51	2	19353·3	5151·48	2	19406·0
5165·15	4	19354·6	5151·15	4⊙	19407·2
5164·91	2	19355·5	5150·80	2	19408·5
5164·63	4s	19356·6	5150·45	5	19409·9
5164·26	2s	19358·0	5150·05	4	19411·4
5163·90	4s	19359·3	5149·76	4	19412·5
5163·58	2	19360·5	5149·41	3	19413·8
5163·22	2	19361·9	5149·13	2	19414·8
5162·90	2	19363·1	5148·82	3	19416·0
5162·43	5	19364·8	5148·26	4	19418·1
5162·14	4	19365·9	5148·00	3	19419·1
5161·81	2	19367·1	5147·74	2	19420·1
5161·45	6	19368·5	5147·47	3	19421·1
5161·16	2	19369·6	5147·16	3	19422·3
5160·82	3	19370·9	5146·74	5	19423 8
5160·47	4	19372·2	5146·10	3	19426·3
5160·26	4	19373·0	5145·59	4	19428·2
5160·00	4	19373·9	5145·25	4	19429·5
5159·71	4	19375·0	5144·71*	5	19431·5

Report of the Committee, consisting of Messrs. A. W. REINOLD, H. G. MADAN, W. C. ROBERTS-AUSTEN, *and* HERBERT M'LEOD, *on the Bibliography of Spectroscopy.*

THE Committee have collected a considerable number of titles of spectroscopic papers during the year, and hope to present a report at the next annual meeting.

Fourth Report of the Committee, consisting of Professor W. A. TILDEN (*Chairman*), Professor ROBERTS-AUSTEN, *and* Mr. THOMAS TURNER (*Secretary*), *appointed to consider the Influence of Silicon on the Properties of Iron and Steel.* (*Drawn up by the Secretary.*)

AT the last meeting of the Association, held at Newcastle-on-Tyne, this Committee presented a report drawn up by Mr. R. A. Hadfield, who, at the invitation of the Committee, was kind enough to make a series of tests with steel melted in crucibles to which definite amounts of silicon were added. The report, though somewhat lengthy, and containing much valuable information, was in reality only a tolerably complete abstract of Mr. Hadfield's work, which has since been published in full in the 'Journal of the Iron and Steel Institute,' 1889, Part II. The results have been discussed by a number of gentlemen who have had special experience in the manufacture of iron and steel, and Mr. Hadfield's statements have met with general acceptance.[1]

The three reports presented by the Committee have therefore included the influence of silicon on ingot iron produced in the Bessemer converter both with and without the presence of manganese, and also the effect produced by silicon in crucible steel. Though there are naturally a number of closely allied subjects which invite investigation, the Committee has now accomplished the chief objects it had in view when it was appointed, and therefore does not ask for reappointment.

Second Report of the Committee, consisting of Professor ROBERTS-AUSTEN (*Chairman*), Sir F. ABEL, Messrs. E. RILEY *and* J. SPILLER, Professor LANGLEY, Mr. G. J. SNELUS, Professor TILDEN, *and* Mr. THOMAS TURNER (*Secretary*), *appointed to consider the best method of establishing an International Standard for the Analysis of Iron and Steel.* (*Drawn up by the Secretary.*)

IN the first Report of the Committee, presented at Newcastle-on-Tyne, the objects of the Committee were defined, and the methods which it was proposed to adopt were indicated. It was arranged that five samples of steel, in the form of fine turnings or drillings, should be prepared under the superintendence of Professor Langley, and that these samples should contain as nearly as possible 1·3, 0·8, 0·4, 0·15, and 0·07 per cent. of carbon respectively. It was further arranged that the samples so prepared should be divided among the respective committees in the United Kingdom, America, France, Germany, and Sweden, and in each country analyses should be performed by not more than seven chemists of repute, and that from the results so obtained the actual composition of the samples should be ultimately deduced.

When the last Report was presented four of these samples had been prepared, and had been despatched in air-tight leaden cases to the respective committees in the five countries above mentioned; but at the time the Report was presented the cases consigned to the British Association Committee had not arrived. These were very shortly afterwards received

[1] See *Jour. Iron and Steel Inst.* 1889, II. 222–255

in good condition, and were opened by the Secretary, and under his direction were hermetically sealed in small glass tubes, each containing about 20 to 30 grammes, as arranged by the Committee.

It was anticipated that the fifth sample would have been prepared shortly after the last Report was presented, but this sample has not yet been received, and its production has apparently been delayed by the fact that the American Committee has entered upon an investigation of the relative accuracy of different processes of analysis, which, though of great interest and importance, was not included in the suggestions which were originally adopted. The result was that delay took place before the analysts in the United Kingdom were supplied with their samples, as it was intended to forward the five standards together. The four samples were, however, distributed as arranged after a few months' delay, and in most cases the analyses have been completed, and the results have been returned to the Secretary of the Committee. The fifth standard will be sealed in glass tubes in the same way as the others immediately it is received, and the analysts will be at once supplied with their sample tubes for examination.

In the meantime the Committee cannot discuss the results which have been received, but it is probable a third and final report will be presented to the Association at its next meeting.

Report of the Committee, consisting of Dr. RUSSELL, Captain ABNEY, Professor HARTLEY, Professor RAMSAY, *and* Dr. RICHARDSON (*Secretary*), *appointed for the investigation of the Action of Light on the Hydracids of the Halogens in presence of Oxygen.* (*Drawn up by* Dr. RICHARDSON.)

THE Committee have to report that further experiments have been made on the decomposition of chlorine water by light. It is found that the presence of 10 per cent. of hydrochloric acid prevents all decomposition, even after long exposure to sunshine. The behaviour of aqueous solutions of pure bromine and iodine, under the influence of sunlight, has been investigated. The free and combined halogen in solution was estimated after an exposure to light extending over fourteen months. The analytical results are embodied in the following tables.

Bromine water.—In a dilute solution (containing 0·16 per cent. Br) as much as 57 per cent. of the total bromine is converted into hydrogen bromide; in a saturated solution the minimum amount of decomposition occurs, again increasing with further additions of bromine.

Table showing the Decomposition of Water by Bromine in Sunlight after Fourteen Months' Exposure.

Weight of bromine taken	Weight of bromine in solution	Per cent. free bromine	Per cent. combined bromine	Bromine as HBr in 100 parts H_2O
16·0	3·78	95·24	4·76	0·18
5·0	3·7	95·59	4·41	0·16
3·8	3·36	98·13	1·87	0·067
—	0·26	72·31	27·69	0·072
—	0·156	42·70	57·30	0·095

Iodine water.—Two series of experiments were made with solutions of iodine; in the first carbon dioxide occupied the space above the liquid. The mean result of six experiments shows that 8·3 per cent. of the total iodine in the solution had been converted into hydrogen iodide. In the second series the carbon dioxide was replaced by air; the mean of four experiments shows that 14·2 per cent. of the total iodine was present as hydrogen iodide.

Table showing the Decomposition of Water by Iodine in Sunlight, exposed Fourteen Months.

Iodine taken in 100 ccs. water	Free iodine in grms.	Combined iodine in grms.	Total iodine in solution	Per cent. free iodine	Per cent. combined iodine
SERIES 1.—CO_2 ABOVE THE LIQUID					
5·0 grms.	·032	·0031	·035	90·80	9·2
3·4 "	·039	·0027	·042	93·63	6·37
1·6 "	·038	·0049	·043	89·55	11·45
1·0 "	·034	·0033	·037	91·14	8·86
0·4 "	·032	·0038	·036	89·35	10·65
0·16 "	·030	·0014	·031	96·34	3·66
SERIES 2.—AIR ABOVE THE LIQUID.					
3·0 grms.	·057	0·0129	·070	83·63	18·39
1·07 "	·042	0·0060	·048	87·28	12·72
1·8 "	·032	0·0046	·037	87·66	12·34
0·03 "	·025	0·0039	·029	86·96	13·04

Further experiments have been made on the oxidation of gaseous hydrogen bromide in sunlight. The presence of free bromine exercises a retarding influence on the decomposition. This was shown to be the case where a mixture of hydrogen bromide, bromine, and oxygen were exposed to light. After a given period 1 per cent. of bromine was set free from the hydrogen bromide, whilst in a second experiment, in which no free bromine had been added, 10 per cent. of bromine was liberated. (The exposure to light was the same in both cases.) It has already been stated that the decomposition of hydrogen chloride is retarded by the presence of free bromine. With regard to the oxidation of aqueous solutions of hydrobromic acid by light, it is observed that in a 7 per cent. solution bromine is set free, whilst in a more dilute solution no oxidation occurs.

Rise in temperature facilitates the oxidation of gaseous hydrogen bromide, and it was found that when a mixture of the moist bromide with moist oxygen was exposed to light at a temperature between 75° and 85° much bromine was set free, as was shown by the deep red colour of the gas; whilst in a corresponding experiment conducted at the ordinary temperature (15°–25°) only a faint yellow colour was observed.

With hydrogen chloride, on the other hand, decomposition appears to be retarded by rise in temperature; thus moist hydrogen chloride and oxygen gave 10 per cent. free chlorine when heated to 75°–85°, and 29 per cent. free chlorine when exposed at the ordinary temperature. Fresh and fuller experiments are being made on this part of the subject with a view to further verifying these results.

Third Report of the Committee, consisting of Professor H. E. ARMSTRONG, Professor W. R. DUNSTAN (*Secretary*), Dr. J. H. GLADSTONE, Mr. A. G. VERNON HARCOURT, Professor H. M'LEOD, Professor MELDOLA, Mr. PATTISON MUIR, Sir HENRY E. ROSCOE, Dr. W. J. RUSSELL (*Chairman*), Mr. W. A. SHENSTONE, Professor SMITHELLS, *and* Mr. STALLARD, *appointed for the purpose of inquiring into and reporting upon the present Methods of Teaching Chemistry.* (*Drawn up by* Professor DUNSTAN.) *To which is appended a paper by* Professor ARMSTRONG *on* '*Exercises in Elementary Experimental Science.*'

IN their second report, which was presented at the Newcastle-on-Tyne meeting, the Committee gave an account in some detail of the general lines which in their opinion an elementary course of instruction in physical science might most profitably follow. During the past year the Committee have been principally engaged in collecting and comparing the regulations with respect to Chemistry which are issued by the more important of the examining bodies in the kingdom, in order to discover how far their requirements are in harmony with such a course of instruction as that suggested by the Committee. Since the information which has been collected is of general interest, the greater part of it is here printed. It consists of a brief outline of the noteworthy features in the regulations of the various Examination Boards, and, wherever it appeared necessary, of recent examination papers. The examinations about which information is now given are as follows:—

Oxford and Cambridge Schools Examination Board.
University of Cambridge Local Examinations.
University of Edinburgh Local Examinations.
University of Glasgow Local Examinations.
University of London Matriculation.
University of Durham Certificate for Proficiency in General Education.
Victoria University Preliminary Examination.
College of Preceptors—Professional Preliminary Examination.
Science and Art Department Examination in Chemistry.
Intermediate Education Board for Ireland.
Civil Service of India.
India Forest Service.
Royal Military Academy, Woolwich.
Cadetships, Royal Military College, Sandhurst.
Engineer Students, H.M. Dockyards.

With respect to the regulations which relate to these examinations, the Committee consider it desirable to direct especial attention to the following points.

It is of great importance that natural science should be sufficiently represented on the board which issues the regulations and is responsible for the proper conduct of the examination. It is remarkable that although Chemistry is an important subject in the Oxford and Cambridge Schools Examination, no representative of this science is appointed by either University to act on the Examination Board, whilst Oxford does not appoint a representative of any one branch of natural science.

The Committee note with satisfaction that in these examinations, most of which are held to test proficiency in general education, Chemistry is generally included in addition to one or more branches of Experimental Physics, and that in many cases the examination is in part a practical one. An important exception to this statement is found in the case of the University of Durham, which, although it grants a certificate of proficiency in General Education, does not include among the subjects of this examination either Chemistry or any branch of Experimental Science. Science is represented only by Elementary Mechanics, and even this is an optional and not a compulsory subject.

As regards the status occupied by Chemistry and Experimental Physics in public examinations, the position of these subjects is still frequently lower than that of the other principal subjects of examination, and much yet remains to be done to secure the adequate recognition of the educational value of natural science. Attention may here be drawn to the position assigned to physical science by the 'Intermediate Education Board for Ireland,' upon whom devolves the examination of most of the Irish public schools. According to the regulations at present enforced by this board, Natural Philosophy and Chemistry appear as optional subjects, each having a relative value represented by 500 marks, the value of Greek and Latin being assessed at 1,200 marks each. It is to be hoped that the Commissioners may before long see their way to introduce elementary physical science as a compulsory subject of these examinations, and to increase the marks assigned to it beyond the present number of 500, which is less than one-half of that awarded to Greek or Latin (1,200).

Another very anomalous case is that of one of the Civil Service Examinations, viz., the Examination for Engineer Students in H.M. Dockyards. In this examination 'very elementary Physics and Chemistry' are included as a single subject, to which is allotted 100 marks out of a total number of 1,950! In the profession for which this is an entrance examination, applicable to boys who are about to leave a public school, not only is the possession of a scientific habit of mind of the highest moment, but a considerable knowledge of Physics and Chemistry is indispensable.

The Committee are strongly of opinion that some attempt should be made to remedy a conspicuous deficiency in nearly all existing examinational regulations. It is virtually impossible to ascertain in the course of a single short examination, especially when the number of candidates is large, whether sufficient time has been devoted to the study of the elements of physical science to make it of permanent advantage to the student; neither is it possible to determine whether the character of the instruction has been in every respect satisfactory. Periodical inspection of the teaching by properly qualified inspectors, such as is now practised to some extent by more than one Government department, would seem to constitute the best method of dealing with this defect, the reports of the inspectors as well as the students' own record of work testified to by the teacher, being taken into account in awarding prizes, certificates, and grants, in addition to the results of an examination.

With respect to the schedules and examination papers, typical specimens of which are here printed, it will be seen that for the most part they do not aim at an educational training of the kind suggested in the Committee's last report. Although nearly all the examinations included are intended to maintain a high standard in general education, yet, as a rule, the schedule of work proposed and the questions set in the papers are more suitable for those who wish to make a special and detailed study of Chemistry as a science. Insufficient attention is paid to problems, like those suggested in the Committee's last report, designed to develop the powers of accurate observation and correct inference; few of the questions asked are adapted to test the mental power of students, which should have been strengthened and trained by the experimental study of Physics and Chemistry. The great majority of the questions asked involve an enumeration of the properties and modes of preparation of different chemical substances; but this by itself is a wholly unsatisfactory method of ascertaining whether a student has derived benefit from experimental work. The mere writing out by the student of methods of preparation of individual substances is no proof that he has learned Chemistry. The Committee are of opinion that it is not advisable to ask young students to give purely formal definitions of chemical terms. A glance at the examination questions appended will show that definitions of such terms as *atomic weight, molecular weight, water of crystallisation, acid, base, salt*, are often demanded. Such questions encourage many students to learn by rote certain forms of words without attempting to grasp the facts and generalisations which those words summarise. Moreover, as many, if not most, of the terms used in Chemistry cannot be defined, the demand for definitions of these terms by examiners leads to a pernicious and unscientific way both of teaching and learning, by which an apparent accuracy in the use of phrases is substituted for a real acquaintance with facts and principles. Again, too much attention is often devoted to calculations which, while they furnish useful exercises, do not necessitate any special scientific knowledge. Another noteworthy feature of these examination schedules and papers is the very general exclusion of any reference to organic substances. There appears to be no reason, even in elementary examinations, why the questions should be exclusively confined to inorganic materials. Moreover elementary Organic Chemistry can be made the basis of excellent training in scientific method, especially if the teaching does not follow the formal order or the aim at completeness which are usual in text-books, most of which are written for those who are studying Chemistry as a special subject, and not chiefly for the sake of the educational benefit which may be derived from it. In general elementary teaching at any rate it is unnecessary even to make the conventional distinction between Inorganic and Organic Chemistry.

The foregoing remarks apply not only to school examinations, but also to the various Civil Service examinations, where it is of the highest importance that candidates should have received a sound scientific training. Most of those selected will afterwards fill positions in which the scientific method of dealing with the various problems which will constantly be presented for solution cannot fail to be of the highest value.

It may perhaps be thought that a great deal of what has been said in criticism of the present examinational demands in physical science might more properly have been urged against the teaching. But since the first report of this Committee was issued, in which attention was drawn to the defective character of much of the elementary teaching, it has been repeatedly represented by teachers in schools of every grade that the character of their instruction is necessarily governed by the requirements of examiners, and that if modifications were made by examining boards in the present regulations it would be possible at once to make the corresponding changes in the methods of teaching.

The obvious conclusion is that the necessary reforms can only be brought about by the active co-operation of examiners and teachers.

OXFORD AND CAMBRIDGE SCHOOLS EXAMINATION BOARD.

Members of the Board.—The Vice-Chancellor of the University of Oxford (*Chairman*); the Vice-Chancellor of the University of Cambridge.

Oxford.—The Principal of Jesus; the Rector of Exeter; the President of Magdalen; the Principal of St. Edmund Hall; J. E. T. Rogers, M.A., *Worcester*; W. Esson, M.A., *Merton*; Alfred Robinson, M.A., *New*; J. R. King, M.A., *Oriel*; T. W. Jackson, M.A., *Worcester*; A. Sidgwick, M.A., *Corpus Christi*; T. H. Grose, M.A., *Queen's*; E. Armstrong, M.A., *Queen's*.

Cambridge.—The Master of Trinity; H. Jackson, Litt. D., *Trinity*; J. S. Reid, Litt. D., *Caius*; A. T. Chapman, M.A., *Emmanuel*; A. Austen Leigh, M.A., *King's*; B. E. Hammond, M.A., *Trinity*; E. S. Shuckburgh, M.A., *Emmanuel*; J. B. Lock, M.A., *Caius*; R. T. Glazebrook, M.A., *Trinity*; E. W. Hobson, M.A., *Christ's*; J. H. Gray, M.A., *Queens'*; W. Welsh, M.A., *Jesus*.

Secretaries.—E. J. Gross, M.A., *Caius College, Cambridge*; P. E. Matheson, M.A., *New College, Oxford*.

REGULATIONS.

Part I.—Examination of Schools.

A School Examination, held under the authority of the Board, shall be of one or more of the following kinds:—

(*a*) Such an Examination in the general work of the school, extending either to the whole school or to portions of the school to be selected with the approval of the Board, as will enable the Examiners to report generally upon the School work.

(*b*) Such an Examination in any main subject of instruction, extending either to the whole school or to portions of the school to be selected with the approval of the Board, as will enable the Examiners to report on the standard reached in that subject.

(*c*) Such an Examination of the highest division of the school as will enable the Examiners to report upon the general work of that division, and, if required, to place the boys in order of merit, and to award exhibitions, scholarships, and prizes.

Applications to the Board for the appointment of Examiners shall specify the kind or kinds of Examination desired by the authorities of the school.

Part II.—Higher Certificates.

The papers shall be set

(1) At every school the authorities of which desire that these papers shall form part of a School Examination, provided that such School Examination be held at the time specified in Regulation 1, and be conducted by Examiners appointed by the Board;

(2) At Oxford, Cambridge, or such other centres as the Board may appoint.

The Certificates shall be awarded by the Board upon the reports of the Examiners for Certificates. When the papers set for Certificates form part of a School Examination they shall be reported on—

(1) By the School Examiners for the purposes of the School Examination;

(2) By the Examiners for Certificates for the purpose of awarding Certificates.

The Examination for Certificates shall include the following subjects:—

Group I.

(1) Latin.	(3) French.
(2) Greek.	(4) German.

Group II.

(1) Mathematics (elementary). | (2) Mathematics (additional).

Group III.

(1) Scripture Knowledge. (3) History.
(2) English.

Group IV.

(1) Natural Philosophy (Mechanical Division).
(2) Natural Philosophy (Physical Division).
(3) Natural Philosophy (Chemical Division).
(4) Botany.
(5) Physical Geography and Elementary Geology.
(6) Biology.

Every candidate shall be required to satisfy the Examiners in at least four subjects. These subjects shall be taken from not less than three different groups, except in the following cases:—

(*a*) Candidates who satisfy the Examiners in one subject taken from Group II or Group IV. Such candidates may offer three subjects taken from Group I.

(*b*) Candidates who have already obtained a Certificate. Such candidates may offer four subjects taken from not less than two different groups.

No candidate shall be allowed to offer more than six subjects, Elementary and Additional Mathematics being reckoned for the purposes of this clause as one subject.

Certificates shall also be awarded to candidates from schools who satisfy the Examiners in two subjects taken from Group I, in one subject taken from Group II or IV, and in such portions of two or more of the subjects included in Group III as may be accepted by the Board as fully equivalent in amount and difficulty to any one of the three subjects included in the group.

The Examination in the Physical Division of Natural Philosophy shall include—

(*a*) Elementary Electricity and Magnetism: viz., phenomena of electric excitement; opposite electrical states; conductors and insulators; electromotive force and potential; phenomena of current (or discharge) in conductors and in air; laws of static induction, and the accumulation of electricity; simple phenomena of magnetism and of magnetic induction and terrestrial magnetism; electromagnets; influence of the electric current on a magnetic needle; sine and tangent galvanometers; laws of resistance; Ohm's law; laws of divided currents; laws of electrolysis; the application of the foregoing principles and laws to simple problems and to instruments, including the electric instruments in common use.

(*b*) The experimental laws of Heat in relation to expansion, liquefaction, and vaporisation; the more important properties of vapours and gases; specific heat; latent heat; the transmission of heat; the absorption and reflection of radiant heat; the production of heat; the mechanical equivalent of heat; thermometry and calorimetry.

(*c*) Elementary Optics: viz., the phenomena and laws of the transmission, reflection, and refraction of light; the formation of images; the action of prisms and simple lenses; vision; the principles and optical construction of telescopes, microscopes, and other simple instruments.

(*d*) The elementary parts of Inorganic Chemistry, including the simple combinations of the principal elements, and the laws of chemical combination; atmospheric air and the phenomena of combustion.

Candidates who offer the Physical Division of Natural Philosophy shall be required to satisfy the Examiners in (*a*) and at least two of the three (*b*), (*c*), (*d*).

The knowledge expected from the Candidates shall be such as may be acquired from an experimental treatment of the subjects.

The Examination in the Chemical Division of Natural Philosophy shall include—

(*a*) The fundamental principles of Elementary Inorganic Chemistry, including the characteristics of chemical change; elements and compounds; laws of chemical combination; combining and equivalent weights; the chemical properties of the more important elements and their commoner compounds.

(*b*) Practical analysis; experiments to illustrate the generally applicable methods of preparation and the characteristic reactions of the more important elements and their commoner compounds, with the distinctive properties of acids, bases, and simple salts.

(*c*) Elementary Electricity and Magnetism: viz., phenomena of electric excitement; opposite electrical states; conductors and insulators; electromotive force and potential; phenomena of current (or discharge) in conductors and in air; laws of static induction, and the accumulation of electricity; simple phenomena of magnetism and of magnetic induction and terrestrial magnetism; electromagnets; influence of the electric current on a magnetic needle; sine and tangent galvanometers; laws of resistance; Ohm's law; laws of divided currents; laws of electrolysis; the application of the foregoing principles and laws to simple problems and to instruments, including the electric instruments in common use.

(*d*) The experimental laws of Heat in relation to expansion, liquefaction, and vaporisation; the more important properties of vapours and gases; specific heat; latent heat; the transmission of heat; the absorption and reflection of radiant heat; the generation of heat; the mechanical equivalent of heat; thermometry and calorimetry.

(*e*) Elementary Organic Chemistry; the determination of the empirical formulæ of organic compounds, from the data of analysis; the general properties of the simpler organic compounds.

Candidates who offer the Chemical Division of Natural Philosophy shall be required to satisfy the Examiners in (*a*) and in (*b*) and in at least one of the three (*c*), (*d*), (*e*).

The knowledge expected from Candidates shall be such as may be acquired from an experimental treatment of the subjects.

EXAMINATION FOR LOWER CERTIFICATES.

[N.B. *This examination is adapted for candidates of sixteen years of age.*]

5. The Examination shall include the following subjects:—

Group I.

(1) Latin.
(2) Greek.
(3) French.
(4) German.

Group II.

(1) Arithmetic.
(2) Additional Mathematics.

Group III.

(1) Scripture Knowledge.
(2) English.
(3) English History.
(4) Geography.

Group IV.

(1) Mechanics and Physics.
(2) Physics and Chemistry.
(3) Chemistry and Mechanics.

Candidates may also offer in addition Geometrical Drawing.

6. In order to obtain a Lower Certificate a candidate shall be required to satisfy the Examiners in five subjects taken from not less than three Groups, of which Groups I and II must be two. Candidates shall be required to answer the questions so as to satisfy the Examiners that they have an adequate knowledge of English Grammar and Orthography, and shall also be required to write a good and legible hand.

The Examination in Chemistry shall include—

The principles in Chemistry, illustrated by the properties of hydrogen, chlorine, bromine, iodine, oxygen, sulphur, nitrogen, phosphorus, carbon, potassium, sodium, zinc, iron, copper, silver, mercury, lead, chlorides, oxides, sulphides, ammonia, marsh gas, nitrates, sulphates, carbonates, and phosphates, together with electrolysis, and the thermal effects attending chemical action.

The Examination in Physics shall include—

(*a*) *Heat.* The experimental laws of heat in relation to expansion, vaporisation, and liquefaction; specific heat; latent heat; radiant heat; thermometry; calorimetry; the production of heat.

Optics. The phenomena, and laws of the transmission, reflection, and refraction of light; the formation of images; the action of simple lenses; vision.

(*b*) *Electricity and Magnetism.* The elementary principles of electrostatics, conductors, and insulators; the electrophorus; the electric current and simple form of cells; simple phenomena of magnetism; the effect of a current on a magnetic needle; Ohm's law.

No candidate shall offer both (*a*) and (*b*).

There is no 'Practical Chemistry' in this Examination.

EXAMINATION FOR COMMERCIAL CERTIFICATES.

[N.B.—*This examination is adapted for candidates of about sixteen years of age. The examination will be open to all persons, whether under instruction at a School of the highest grade or not. In the latter case the Certificates gained will be granted on the authority of the Oxford Delegacy alone.*]

The Examination shall include the following subjects:—

Group I.

(1) Latin.
(2) French.
(3) German.
(4) Spanish.
(5) Italian.

Group II.

(1) Arithmetic.
(2) Algebra.

Group III.

(1) English.
(2) Geography.
(3) English History.
(4) Political Economy.

Group IV.

(1) Drawing.
(2) Inorganic Chemistry.
(3) Organic Chemistry.
(4) Mechanics—including Hydrostatics and Pneumatics.
(5) Electricity and Magnetism.
(6) Sound, Light, and Heat.

6. In order to obtain a Commercial Certificate a candidate shall be required to satisfy the Examiners in—

(*a*) At least one of the four languages:—French, German, Italian, and Spanish.

(*b*) Arithmetic and Algebra.

(*c*) English and Geography.

(*d*) One of the following subjects:—Latin, English History, Political Economy, or one of the subjects in Group IV.

Great weight will be attached to good handwriting and spelling and to an orderly style.

A candidate who produces a Certificate showing that he has obtained a First Class in the Elementary Stage, or a First or Second Class in the Advanced Stage, of the Examination held by the Science and Art Department, South Kensington, in any of the subjects in Group IV, will be considered to have satisfied the Examiners without passing the Board's Examination in such subject or subjects, and the fact will be endorsed on the Certificates granted by the Board.

18. The Examination in Inorganic Chemistry shall include—

(*a*) Characteristics of chemical change. Elements and compounds. Laws of chemical combination. Combining and equivalent weights. Chemical symbols and notation. Classification of elements into groups in accordance with their chemical similarities. Division of compounds into acids, alkalis, salts, basic and acidic oxides, &c., and the relations between the properties and the compositions of these different classes of compounds. Outlines of the chemical applications of the molecular and atomic theory.

The student will be expected to illustrate the foregoing subjects by making use of the chemical properties of the following elements and their commoner compounds:—hydrogen, oxygen, sulphur, chlorine, bromine, nitrogen, phosphorus, sodium, potassium, calcium, magnesium, zinc, mercury, iron, and chromium.

(*b*) In *practical Inorganic Chemistry*, the student will be expected to perform simple experiments, illustrative of the generally applicable methods of preparation and the characteristic properties of *acids, bases, salts, acidic* and *basic oxides.* The experiments will involve an acquaintance with easy qualitative analysis, and will be restricted to compounds of the elements enumerated in the foregoing part of this schedule.

Candidates who offer Inorganic Chemistry will be required to satisfy the Examiners in (*a*) and (*b*).

19. The Examination in Organic Chemistry shall include—

(*a*) The determination of the empirical formulæ of organic compounds from the data of analyses.

The general properties of the following classes of compounds, and the chief reactions by which the relations between the different classes are established, illustrated in each case by one or two of the best studied members of the class:—paraffins, olefines, ethylic alcohols, ethers, ethereal salts, mono-, di-, and tri-basic acids, aldehydes, ketones, amines, amides.

(*b*) In *practical Organic Chemistry*, the student will be required to prepare one or more compounds chosen from the foregoing classes.

Candidates who offer Organic Chemistry will be required to satisfy the Examiners in (*a*) and (*b*).

Higher Certificates.

The Higher Certificates give exemption, under certain conditions, from the following Examinations:—

I. The first Examinations in the University course at Oxford and Cambridge —Responsions and the Previous Examination.

A. The Certificate exempts from Responsions when it shows that the candidate has satisfied the Examiners in Greek, Latin, and Elementary Mathematics. Candidates who pass with distinction in Latin or Greek, or who pass (with or without distinction) in French or German, are exempted from the Examination in an Additional Subject at Responsions, which must be taken by candidates intending to enter for the Final Honour Schools in Mathematics, Physical Science, or Law, if they wish to be excused from the Classical Subjects hitherto required in the First Public Examination (Pass).

B. (1) From the first part of the Previous Examination when it states that the candidate has satisfied the Examiners in Scripture Knowledge (showing a satisfactory acquaintance with the Greek Text), Greek and Latin; (2) from the second part when the candidate has passed in Scripture Knowledge, Elementary and Additional Mathematics; (3) and from the Examination of the Additional Subjects when the Candidate has passed in Trigonometry, Statics, Dynamics, or French or German. Exemptions obtained by Certificates which were granted before October 1, 1886, still hold good. For these exemptions the Candidates must be members of a school at the time of the Examination.

II. At Oxford—the Matriculation Examination of the following Colleges and Halls: University, Balliol, Merton, Exeter, Oriel, Queen's, New College, Lincoln, Brasenose, Corpus, Christ Church, Trinity, St. John's, Jesus, Wadham, Pembroke, Worcester, Keble, and Hertford Colleges; St. Mary and St. Edmund Halls; and of the Delegates of Non-Collegiate Students.

Candidates who have passed in one Examination in two of the languages, Latin, Greek, French, or German, and in Mathematics, are exempted from the First Examination for Women.

The Certificates also under certain conditions qualify for entrance at Lady Margaret Hall and Somerville Hall.

At Cambridge—The Entrance Examinations of all Colleges where such Examinations are held.

The Certificates also give exemption from the Entrance Examinations at Girton College for Women; and, under certain conditions, qualify for entrance at Newnham College.

Candidates wishing to be exempted from the Matriculation or Entrance Examination of any College or Hall, or of the Oxford Delegates of Non-Collegiate Students, should apply to the authorities of the College or Hall, or to the Delegates, for information respecting the conditions under which such exemption is granted.

III. Holders of Certificates are exempted from the Preliminary Examinations of the Incorporated Law Society.

IV. Such portions of the Examination of the Royal Institute of British Architects as appear from the Certificate to have been included in the Examination passed by the candidate.

V. Such portions of the Examination of the Surveyors' Institution as appear from the Certificate to have been included in the Examination passed by the candidate.

VI. The Certificates are also accepted by the General Council of Medical Education as evidence that the candidate has passed a Preliminary Examination.

The subjects in which the candidate satisfies the Examiners must include Latin, Elementary Mathematics, Natural Philosophy (Mechanical Division), and one of the following: Greek, French, German, Botany, Chemistry.

VII. Candidates for first appointments in the Army, and for admission to the Royal Military Academy at Woolwich, who have obtained Certificates are exempted, at the discretion of the Civil Service Commissioners, from the non-competitive portions of the Examinations prescribed in the Regulations of April 1873, so far as the Certificate shows that the candidate has satisfied the Examiners in the subjects included in these portions of the Examinations.

LOWER CERTIFICATES.

The Lower Certificates give exemption, under certain conditions, from the following Examinations:—

1. The Preliminary Examination of the Pharmaceutical Society of Great Britain, provided that the candidate obtains a First Class in Latin, Arithmetic, and English.

2. The Preliminary Examination for admission to the Royal Military College, provided that the Certificate shows that its Holder obtained a First Class in each of the following subjects, viz. Arithmetic, Additional Mathematics, English and Geography, and in either French or German; and passed in Geometrical Drawing.

3. The Certificate is also accepted by the General Council of Medical Education as evidence that the candidate has passed a Preliminary Examination. The Certificate must show that the candidate has satisfied the Examiners in English, Latin, Arithmetic, Additional Mathematics, and in Physics; and also in one of the following optional subjects: Greek, French, German, Chemistry.

NATURAL PHILOSOPHY. CHEMICAL DIVISION.

HIGHER CERTIFICATES.

You are expected to satisfy the Examiners in at least ONE *of the three sections, C, D, E.*]

ELECTRICITY AND MAGNETISM.

1. Describe a gold-leaf electroscope. How would you use it to demonstrate the existence of opposite electrifications?

2. A strong bar magnet is fixed in a vertical position with its north pole uppermost, and a small magnetic compass is held near it at different heights, but always at the same horizontal distance from the bar: describe the effects observed with reference to (*a*) the time of swing, (*b*) the direction of pointing of the compass. What information do these observations give as to the magnetic field about the bar?

3. Describe the construction and action of a Daniell's cell, and state what the advantage of such a cell is in maintaining a current in a circuit of small resistance.

4. A current from three cells is passed through electrolytic cells in succession, one containing copper sulphate solution, another sodium sulphate solution, another acidulated water: state what occurs in each electrolytic cell, and what relation there is between the amounts of action in the different cells. What would be the effect of doubling the current through each cell?

5. Describe a form of tangent galvanometer, and explain the principles involved in its use. How would you, by means of it, determine the resistance of a given conductor, if you were provided with a battery and wires of known resistance?

HEAT.

6. A Centigrade thermometer gives a reading 51° when set in a certain hot bath: what reading should a correct Fahrenheit thermometer give when set alongside of it? What are meant by the fixed points on a thermometer? How are they determined?

7. What do you understand by the latent heat of fusion of ice? How would you show that its value is 80 when the Centigrade scale is used? What is its value when the Fahrenheit scale is used?

8. State the difference between radiation and conduction. Explain fully the formation of dew.

9. Describe a method of determining the coefficient of linear expansion of a given metal, and state carefully how, from the observations taken, the coefficient is deduced.

ORGANIC CHEMISTRY.

1. A compound of carbon, oxygen, and hydrogen is analysed, and the results are stated in percentages of the three elements: what further data are required before an *empirical formula* can be assigned to the compound? When the necessary data are given, how would you proceed to determine the formula? What information is conveyed by the *empirical formula* of a compound?

2. Why is it important to determine the vapour densities of compounds?

3. Glycerin is a trihydric alcohol. What is meant by this statement?

4. By what reactions can each of the following compounds be prepared from a paraffin: (i.) a monohydric alcohol, (ii.) an ether, (iii.) an aldehyde, (iv.) a monobasic acid? Illustrate your answer by describing the preparation of (*a*) $C_2H_5.OH$, (*b*) $(C_2H_5)_2O$, (*c*) $CH_3.CHO$, (*d*) $CH_3.COOH$, from ethane (C_2H_6).

5. Point out some of the chief differences between the fatty (or paraffinoid) compounds and the aromatic (or benzenoid) compounds.

6. Show by reactions that the alcohols are analogous in their chemical properties to the metallic hydroxides, and that the ethers are analogous to the metallic oxides.

7. The following formulæ are given to acetic acid : (*a*) $C_2H_4O_2$, (*b*) $CH_3.COOH$: indicate some of the advantages of the second formula as compared with the first.

INORGANIC CHEMISTRY.

1. Explain briefly the meaning of the following chemical symbols and equations:

$$O;\ O_2;\ 2KClO_3 = 2KCl + 3O_2;\ 2H_2 + O_2 = 2H_2O.$$

2. Describe, as fully as you can, one instance of a chemical change, and one of a physical change; and point out the chief differences between them.
3. With 1 part by weight of hydrogen there combine 16 parts by weight of sulphur; with 8 parts by weight of oxygen there combine, in one case 8 parts by weight of sulphur, and in another case 5·33 parts by weight of sulphur. State in general terms how you would determine whether 5·33, 8, 16, or a common multiple of these numbers, would be the best combining weight to use for sulphur.
4. What do you understand by the *chemical* properties of an element? Illustrate your answer by describing what you regard as the chief chemical properties of *any one* of the following elements: chlorine, sulphur, magnesium, iron, chromium.
5. The compounds KOH and NaOH are called *alkalis*: why are these compounds classed together under a common name, and what is the chemical meaning of the term *alkali*?
6. You are given an aqueous solution of two salts, one of which is much more soluble than the other: how would you proceed to effect a partial separation of the salts?
7. Sugar is composed of the three elements carbon, hydrogen, and oxygen: how can this statement be proved? Why are the substances carbon, hydrogen, and oxygen called elements?

PRACTICAL WORK.

Write out a clear and full description of all your experiments; state very carefully and fully the reasoning on each result obtained.

[*Not more than* TWO *questions to be attempted.*]

[*Time allowed*, 3 *hours.*]

1. Determine, as far as you can by qualitative experiments, whether the substance A is a mixture of two salts or a double salt.
2. To B add a solution of bleaching-powder, and heat to boiling; to C add dilute sulphuric acid; from the results observed identify B and C as far as you can.
3. The substance D is either an acid, a base, or a salt: find which it is.

LOWER CERTIFICATES.

CHEMISTRY.

I.

1. Explain why water is regarded as a *compound*, and air as a *mixture*.
2. How may hydrogen be liberated from water? If you wished to obtain 44·8 litres of hydrogen by dissolving iron or zinc in acid, what weight of each should be used? [Fe = 56, Zn = 65, 11·2 litres of hydrogen weigh one gramme.]
3. How is hydrochloric acid obtained? For what reasons is it called an acid? How are metallic salts formed from it? Give examples.
4. Describe briefly and explain what changes take place in the following reactions: (*a*) potassium nitrate with strong sulphuric acid; (*b*) diluted nitric acid with copper; (*c*) strong nitric acid with phosphorus; (*d*) ammonium nitrate if exposed to heat.
5. What oxides are formed when sulphur and phosphorus burn, and what acids are formed by the union of the oxides with water?

6. Explain the meaning of the term allotropy. How can plastic sulphur be obtained, and how is it shown to be identical with common sulphur?

7. What methods are commonly used to obtain solutions of (*a*) chlorine, (*b*) hydrogen sulphide, (*c*) ammonium sulphide? For what purposes are these solutions used?

8. Given metallic copper and lead, how would you obtain their several oxides? Describe each shortly.

II.

1. Explain briefly the terms atom, atomic weight, acid, base, salt, alkali, precipitate, sublimate, distillate.

2. When copper oxide is heated in hydrogen some water is formed: draw and describe the apparatus by which the composition of water by weight is determined from this fact.

3. What is combustion? Give some account of the chemical changes which go on when a candle burns, or charcoal, sulphur, phosphorus, or magnesium burns in air. Mention some examples of combustion in other gases.

4. When sulphuric acid is heated with salt, or with a mixture of salt and peroxide of manganese, gases are obtained. Give equations for the actions, and point out some important differences in the two gases.

5. Mention several methods for obtaining gaseous sulphur dioxide from sulphuric acid, and explain how the dioxide can be converted into sulphuric acid. What are the chief properties of the gas?

6. What compounds does hydrogen form with (*a*) bromine, (*b*) nitrogen, (*c*) sulphur, (*d*) phosphorus? Give a brief account of each, and explain how they are obtained.

7. Give an account of the chemical actions, if any, which take place when iron, copper, mercury, or lead is heated in air, heated in nitric acid, heated in hydrochloric acid.

8. Explain how caustic soda is made from common salt.

COMMERCIAL CERTIFICATES.

Inorganic Chemistry.

I.

1. Why is the red solid produced by heating clear phosphorus at 240° in a flask full of carbonic-acid gas considered to be an element and not a compound?

2. Arrange the elements hydrogen, oxygen, chlorine, sulphur, bromine, nitrogen, sodium, phosphorus, potassium, calcium, magnesium, zinc, mercury, iron, and chromium in groups, in accordance with their chemical similarities. Give reasons for your classification.

3. Why do many chemists prefer to represent the combination of hydrogen with chlorine by the equation $H_2 + Cl_2 = 2HCl$ rather than by the simpler expression $H + Cl = HCl$?

4. How would you show by experiment that each of the following bodies contains hydrogen?—

(*a*) Water. | (*b*) Hydrochloric acid. | (*c*) Ammonia.

5. What do people mean when they speak of water being *hard* or *soft*? How would you distinguish a sample of hard water from one of soft water? Explain the difference between permanent and temporary hardness in water.

6. What is the smallest quantity of mercury that would be required in order to deprive 20 litres of air (measured under standard conditions) of all its oxygen? [Hg = 200.]

7. What weight of sulphur would be required to produce enough sulphurous acid to reduce 10 grams of chromium trioxide (chromic acid CrO_3) to chromium sesquioxide (Cr_2O_3)? [S = 32; Cr = 52.]

8. Describe the method by which Cavendish determined the composition of water.

II.

Practical Examination.

Perform the following continuous series of experiments, and describe accurately what you observe to happen at each successive step of the work. *a.* Dissolve a portion of the substance *X* in diluted hydrochloric acid and pass the liberated gas in excess into a slightly acidified solution of ferric chloride (perchloride of iron). *b.* Boil until free from smell, and then filter the above solution. Add to separate portions of the filtered liquid, carbonate of ammonia and yellow prussiate of potash respectively. *c.* Add carbonate of ammonia and yellow prussiate of potash respectively to separate portions of the original solution of ferric chloride. *d.* Dissolve another portion of the substance *X* in diluted nitric acid. *e.* Filter the solutions you have made of the substance *X* in hydrochloric acid and in nitric acid respectively, and test each filtered liquid with the following reagents:—

I. Sulphuretted hydrogen, before and after (imperfect) neutralisation of the liquid.
II. Chloride of barium.
III. Excess of potash, and subsequent ebullition of the mixture.

UNIVERSITY OF CAMBRIDGE.

LOCAL EXAMINATIONS.

Junior Examination.

Certificates are granted to those students who, having already passed a preliminary examination in reading, writing, English grammar, and arithmetic, have also passed in not less than two of the following subjects: Religious Knowledge; English, Latin, or Greek; French or German; Mathematics, Natural Philosophy; (two of the following departments: Chemistry and Practical Chemistry, Statics, Dynamics, &c., Heat;) Zoology or Botany. No detailed schedules are issued.

Senior Examination.

The Examination deals with a more advanced knowledge of the same subjects as are included in the Junior Examination. No detailed schedules are issued. The following statement is made with reference to Chemistry:—'(*a*) The general principle of chemical science and the facts which illustrate them. (*b*) Practical Chemical Analysis. Credit will be given for well-chosen experiments, good observations, precisely recorded and well-drawn inferences from them. A fair knowledge of Inorganic Chemistry will entitle a student to pass in these divisions.

'The questions will relate to such compounds and reactions as are typical or characteristic.

'The following elements and their compounds are to be omitted:—beryllium, cæsium, cerium, didymium, erbium, gallium, indium, iridium, lanthanum, molybdenum, niobium, osmium, palladium, rhodium, rubidium, ruthenium, samarium, scandium, tantalum, terbium, thallium, thorium, titanium, tungsten, uranium, vanadium, ytterbium, yttrium, zirconium.

'For the Junior Students, no knowledge of carbon-compounds will be expected, beyond the oxides of carbon, the carbonates, marsh gas, and olefiant gas.

'For the Senior Students, the knowledge of Organic Chemistry expected will be limited to cyanogen and the principal cyanides, paraffins, monatomic alcohols and ethers of the ethylic type, fatty acids of the acetic type.'

EXAMINATION FOR COMMERCIAL CERTIFICATES.

The subjects of examination will be as follows:—

I.

(1) LETTER-WRITING. (2) PRÉCIS-WRITING.

(3) Taking notes in SHORTHAND of passages read to the student, and extending the notes to produce a *verbatim* report.

To pass in Section I. a student must satisfy the Examiners in I. (1) and I. (2).

II.

(1) ARITHMETIC, with special reference to commercial problems.

(2) ALGEBRA: (*a*) Elementary, including fractions, simple equations of two unknown quantities, and easy quadratic equations with one unknown quantity; (*b*) more advanced, including the Binomial Theorem with positive integral indices, logarithms, and the application of algebra to the calculation of Interest and Annuities.

To pass in Section II. a student must satisfy the Examiners in II. (1).

III.

(1) GEOGRAPHY, Physical and Commercial. A special knowledge of sea and land routes, of centres of industry, and of products will be required.

(2) ENGLISH HISTORY, from the commencement of the reign of Elizabeth to the present time. The questions will bear chiefly on the development of industry and commerce.

To pass in Section III. a student must satisfy the Examiners in III. (1).

IV.

MODERN LANGUAGES: (1) French, (2) German, (3) Spanish, (4) Italian. No books will be set. In each language students will be required (*a*) to write a commercial letter, (*b*) to translate from the language into English, and from English into the language. Opportunities will be afforded at certain centres for students to give evidence of ability to converse in the language.

To pass in Section IV. a student must satisfy the Examiners in (*a*) and (*b*) in at least one language. A student cannot take both Spanish and Italian.

V.

LATIN. No books will be set. The paper will consist of (*a*) passages for translation into English, (*b*) questions on grammar, (*c*) a passage for translation from English into Latin.

VI.

The Elements of POLITICAL ECONOMY, with special reference to the principles of Value, Money, Credit, Banking, Foreign Trade, and the Foreign Exchanges.

VII.

ENGLISH LITERATURE. Shakespeare, *Tempest.* The questions will turn chiefly upon the matter and style of the book, and the construction of sentences.

VIII.

ELEMENTARY PHYSICAL SCIENCE: (1) Inorganic Chemistry, theoretical and practical. (2) Organic Chemistry, theoretical and practical. (3) Mechanics, including Hydrostatics and Pneumatics. (4) Sound, Light, Heat. (5) Electricity and Magnetism.

A student cannot take more than one of the five subjects.

IX.

GEOMETRICAL and MECHANICAL DRAWING: In order to obtain a Certificate a student must pass in Sections I., II., III., IV. No student can take more than two of the Sections V., VI., VII., VIII., IX.

Students who have obtained a First Class in the Elementary stage of the Examination held by the Science and Art Department, South Kensington, in any of the subjects of Section VIII. may have the fact entered upon their Certificate without further examination.

Schedule for Section VIII.

VIII. (1) Inorganic Chemistry, theoretical and practical.

(*a*) *Theoretical.* Characteristics of chemical change; elements and compounds; laws of chemical combination; combining and equivalent weights; chemical symbols and notation; classification of elements into groups in accordance with their chemical similarities; division of compounds into acids, alkalis, salts, basic and acidic oxides, &c., and the relations between the properties and the compositions of these different classes of compounds; outlines of the chemical applications of the molecular and atomic theory. Students must be prepared to use in illustration of these subjects the chemical properties of the following elements and their commoner compounds:—hydrogen, oxygen, carbon, sulphur, chlorine, bromine, iodine, nitrogen, phosphorus, sodium, potassium, calcium, magnesium, zinc, mercury, iron, chromium, aluminium.

(*b*) *Practical.* Students must be prepared to perform simple experiments illustrative of the ordinary methods of preparation and the characteristic properties of acids, bases, salts, acidic and basic oxides. The experiments will require an acquaintance with easy qualitative analysis, and will be restricted to compounds of the elements enumerated in (*a*).

To pass in this subject, students must satisfy the Examiners in (*a*) and (*b*).

VIII. (2) Organic Chemistry, theoretical and practical.

(*a*) *Theoretical.* The determination of the empirical formulæ of organic compounds from the data of analyses. The general properties of the following classes of compounds, and the chief reactions by which the relations between the different classes are established, illustrated in each case by one or two of the best studied members of the class:—paraffins, olefines, ethylic alcohols, ethers, ethereal salts, monobasic, dibasic, and tribasic acids, aldehydes, ketones, amines, amides.

(*b*) *Practical.* Students will be required to prepare one or more compounds chosen from the foregoing classes.

To pass in this subject, students must satisfy the Examiners in (*a*) and (*b*).

CAMBRIDGE LOCAL EXAMINATIONS.

Number of Candidates in Chemistry from 1884–1888.[1]

—	Boys		Girls	
	Theory of Chemistry	Practical Chemistry	Theory of Chemistry	Practical Chemistry
Seniors—				
1884	66	27	23	12
1885	81	49	25	4
1886	80	44	22	11
1887	114	69	32	8
1888	100	48	18	7
	441	237	120	42
Juniors—				
1884	618	298	40	11
1885	681	378	35	6
1886	715	364	30	15
1887	776	407	29	20
1888	829	454	30	18
	3619	1901	164	70

[1] For these statistics the Committee are indebted to the Secretary of the Board.

HIGHER.

1884	15	1887	1
1885	9	1888	19
1886	8		

JUNIOR STUDENTS.

CHEMISTRY.

Candidates must not attempt more than SIX *questions.*

1. Define the terms *atomic weight* and *molecular weight*.

Find the molecular weight of an element, 1 gram of which, in the state of vapour, fills the same space that ·016 gram of hydrogen fills at the same temperature and pressure.

2. Show by what tests, or general characters, you would identify each of the following gases: nitrogen monoxide; sulphur dioxide; ammonia; chlorine.

3. Explain what is usually understood by *valency* or *quanti-valence*.

Given two elements whose chemical symbols are A and B, and whose valencies are x and y respectively, what would be the most probable formula for a compound of them?

4. Describe a method of preparing nitric oxide, and give a sketch of the apparatus you would employ.

Why is the formula of this compound written NO and not N_2O_2?

5. What conclusions would you draw with regard to the chemical characters of the substances *a, b, c,* and *d* respectively, from the following experiments:—*a,* when acted upon by hydrochloric acid, gives a metallic chloride and water only; *b,* when acted upon by hydrochloric acid, gives a metallic chloride, water, and chlorine; *c* liberates iodine from potassium iodide; *d* converts ferric salts into ferrous salts?

6. Describe briefly how metallic lead is obtained from its ores. Show how each of the oxides of lead may be prepared.

7. Explain, in general terms, what takes place when an electric current is passed through a solution of a metallic salt.

8. How is hydrochloric acid prepared?

What weight of hydrochloric acid gas would be necessary in order to completely decompose one gram of silver nitrate?

[H = 1, N = 14, O = 16, Ag = 108, Cl = 35·5.]

PRACTICAL CHEMISTRY.

[N.B.—*Credit will be given for good observations even if the conclusions be incorrect, but no credit will be given for experiments not actually made, or for conclusions without the observations on which they are based.*]

1. Determine the metal and acid-radicle in the salt A. Does it contain anything besides a metal and an acid-radicle?

2. B is the oxide of a metal. Find the metal, and examine the oxide with a view of ascertaining whether it is a *basic oxide, peroxide,* or *acid-forming oxide.*

3. Examine C in the dry way only.

SENIOR STUDENTS.

CHEMISTRY.

1. Nitrogen unites with oxygen to form five oxides: state the chemical laws which these oxides illustrate.

2. Give the characteristics of each of the following classes of oxides:—basic oxides, acid-forming oxides (anhydrides), and peroxides; illustrate your answer by reference to the oxides of the following elements: S, Ba, Cr, H.

3. How can the composition of water (1) by weight, (2) by volume, be determined?

4. One of the chief chemical laws states that there is no loss or gain of mass in any chemical reaction. Describe two experiments to prove the truth of this law.

5. Give the preparation and properties of nitric oxide.

Show how the formula of this gas may be deduced from the following data: 15·6 cc. of the gas passed over heated Cu gives 7·8 cc. of nitrogen; the weight of nitric oxide which fills a certain globe is 3·75 grams, the weight of an equal volume of hydrogen being 0·25 gram.

6. How may the composition of air be determined?

Would the composition of air be represented either by the formula N_4O or $N_4 + O$? Give reasons for your answer.

7. How is mercury extracted from its ores? Show how (*a*) the oxides, (*b*) the nitrates may be obtained from the metal.

8. What is a paraffin? Give the preparation of any paraffin, and state the action of reagents upon it.

Practical Chemistry.

[N.B.—*Credit will be given for good observations even if the conclusions be incorrect, but no credit will be given for experiments not actually made, or for conclusions without the observations on which they are based.*]

1. Find the acid-radicle and the metal in D.
2. E is a mixture: find its composition.
3. F is a metallic salt: prepare a few small pieces of the metal (about the size of a pin's head). Find in which of the common acids the metal is soluble, and which are its chief insoluble compounds. Enclose one of the pieces of metal you obtain in the glass tube, together with a slip of paper with your index number.

EXAMINATION FOR COMMERCIAL CERTIFICATES.

Inorganic Chemistry.

Atomic Weights.—H = 1, O = 16, N = 14, S = 32, K = 39.

1. Explain the meaning of the term 'diffusion,' and describe some experiments by which the phenomena of diffusion in gases can be examined.

One litre of a certain gas diffuses through an opening in the same time as 3·74 litres of hydrogen. Calculate the weight of a litre of this gas from the fact that a litre of hydrogen weighs ·0896 gram.

2. State exactly what you understand by the statements that the equivalent of nitrogen is $4\frac{2}{3}$ and that of sodium is 23. Describe experiments by which you would propose to verify these statements.

3. A current of electricity is passed for some time through a solution of potassium sulphate in water, entering and leaving the liquid through platinum plates; the current is then interrupted and the liquid well stirred; describe important chemical and physical changes that take place during this experiment.

4. Describe methods of obtaining hydroxides or oxides of the metals from sodium chloride, calcium carbonate, ferrous sulphate respectively.

5. Express by an equation the reaction that takes place between a basic oxide and an acid.

One litre of ammonia gas measured at 10° C. and 740 mm. is passed into a solution of sulphuric acid in water and absorbed by the liquid. Assuming that the liquid at the beginning of the experiment contains 4 grams of sulphuric acid, calculate the weight of caustic potash needed to exactly neutralise it after the absorption of the ammonia.

6. Compare and contrast the behaviour of hydrochloric, nitric, and sulphuric acids, both concentrated and dilute, as shown in their action on the common metals.

7. What are the reactions which take place when (*a*) ammonia, (*b*) ammonium

sulphide is added to an aqueous solution of either of the following substances: $AgNO_3$, $HgCl_2$, $FeCl_3$?

8. What are the most striking points of chemical behaviour in which chlorine and bromine resemble each other and differ from sodium?

Practical Chemistry (Inorganic).

[*A full account must be given of all experiments from which any conclusion is drawn, and the chemical changes noticed must as far as possible be explained.*]

1. Examine the substance P to ascertain what class of compounds it belongs to, and if possible identify it.
2. Make a qualitative analysis of the double salt Q.

UNIVERSITY OF EDINBURGH.

LOCAL EXAMINATIONS.

Similar regulations to those of the Oxford and Cambridge Board. The following is the schedule for Chemistry in the Senior Examination:—

Department D.

1. *Chemistry.*—The relations to one another of acids, bases, salts, and metals—oxidation and reduction. The physical characters, methods of preparation, and chemical characters of the following non-metallic elements and their chief compounds:—oxygen, hydrogen, nitrogen, carbon, sulphur, phosphorus, chlorine, bromine, iodine, silicon. The oxides and salts of the following metals:—potassium, sodium, barium, calcium, magnesium, iron, zinc, manganese, chromium, aluminium, cobalt, nickel, copper, mercury, lead, silver, gold, platinum, tin, arsenic, antimony, bismuth.

The following text-books are referred to as indicating the amount and kind of knowledge expected:—Roscoe's 'Lessons in Elementary Chemistry,' Lessons i.-xxvi.; Williamson's 'Chemistry for Students,' Chaps. i.-xxxiii.; Wilson's 'Inorganic Chemistry' (Chambers's Educational Course); Brown's 'Chemistry' (Chambers's Elementary Science Manuals).

D. 1.—Chemistry.

(*Time—One hour.*)

1. Give one method for the preparation of each of the following substances:—
   a. Hydrobromic acid.
   b. Phosphuretted hydrogen.
   c. Potassium permanganate.
2. Describe the action of nitric acid on
   a. Calcium carbonate.
   b. Copper.
   c. Tin.
3. What substances are formed when excess of chlorine is passed into a cool dilute solution of caustic potash?

UNIVERSITY OF GLASGOW.

LOCAL EXAMINATIONS.

These Examinations are similar in scope and character to those of Oxford and Cambridge and Edinburgh.

For the Junior Certificate the following requirements are mentioned in Chemistry, but no detailed schedule is published:—

Chemistry.—Laws of combination, water, atmospheric air, combustion, acids, bases, and salts.

For the Senior Certificate. *Chemistry.*—General principles of Chemistry, including calculations with combining weights. Chemistry of the more important metals, including testing (Roscoe's 'Elementary Chemistry,' Williamson's 'Chemistry for Students,' W. Wilson's 'Inorganic Chemistry').

For the Higher Certificate. No schedule in Chemistry, but the following books are suggested:—Roscoe, 'Lessons in Elementary Chemistry'; Fownes, 'Manual of Chemistry'; Armstrong, 'Organic Chemistry'; Bloxam, 'Chemistry Inorganic and Organic'; Roscoe and Schorlemmer, 'Treatise on Chemistry'; Miller, 'Elements of Chemistry.'

LOCAL EXAMINATIONS.

Junior Certificate.

D. 1.—Chemistry.

1. How can it be demonstrated that water is a compound substance? What is the difference between hard and soft water, and how is it ascertained? Which is the softest natural water?

2. Of the following oxides, which are soluble and which insoluble in water: CuO, K_2O, SO_2, Pb_3O_4, CaO, SO_3, HgO, Fe_2O_3, BaO, P_2O_5, N_2O_2, SiO_2.
How could the insoluble oxides be got into solution?

3. Define 'water of crystallisation' and 'water of hydration,' giving examples.

4. What is combustion? How can it be shown that oxygen will burn with a flame?

5. In chemical nomenclature the terminations -ous, -ic, -gen, -ide, -ate, -ite frequently occur. Give examples of each, and explain their meaning and use.

Senior Certificate.

H. 1.—Chemistry.

1. Three yellow solids contain iodide, phosphate, and arsenite of silver respectively. How could you liberate the acids in each, and identify them?

2. Why is the combining weight of oxygen taken as 16 rather than as 8?

3. What would be the volume in litres of 1 gramme of nitrogen measured at 100° C. and 200 mm. pressure?

4. Write the formulæ of ferrous iodide, chromic fluoride, platinic chloride, baric hypophosphite, chloric acid, metaphosphoric acid.

5. What is the difference between the specific gravity and the density of a body?

UNIVERSITY OF LONDON.

MATRICULATION.

Chemistry.

The following elements and their compounds as enumerated below, their chief physical and chemical characters, their preparation, and their characteristic tests: oxygen, hydrogen, carbon, nitrogen, chlorine, bromine, iodine, fluorine, sulphur, phosphorus, silicon.

Combining proportions by weight and by volume. General nature of acids, bases, and salts. Symbols and nomenclature.

The atmosphere: its constitution; effects of animal and vegetable life upon its composition.

Combustion. Structure and properties of flame. Nature and composition of ordinary fuel.

Water. Chemical peculiarities of natural waters, such as rain-water, river-water, spring-water, sea-water.

Carbon monoxide. Carbon dioxide. Oxides and acids of nitrogen, ammonia, olefiant gas, marsh gas, sulphur dioxide, sulphuric acid, sulphuretted hydrogen.

Hydrochloric acid. Phosphoric anhydride and common phosphoric acid.

UNIVERSITY OF DURHAM.

This University grants a 'Certificate of Proficiency in General Education,' but Chemistry does not form one of the subjects of the examination. Science is represented by elementary mechanics, which is, however, only an optional subject.

VICTORIA UNIVERSITY.

Degrees in Arts, Science, and Law.

Elementary Chemistry is an optional subject (taken more often than not) in the *Preliminary* Examination, which may be passed directly from School or after one year's study in a College of the University.

The syllabus is as follows:—

General properties of matter.
Chemical combination and decomposition.
Preparation, classification, and chemical behaviour of the chief elements and their compounds, especially of the non-metals.
The outlines of Chemical Theory.

PRELIMINARY EXAMINATION.

(Faculties of Arts, Science, and Law.)

Chemistry.

1. What is the relationship between the density of a gas and its molecular weight? How is it proved that nitric oxide has the formula NO and not N_2O_2?

2. An oxide of iron was found by analysis to have the following composition:

Iron	77·7
Oxygen . . .	22·3
	100·0

Find the simplest formula, and explain fully each step taken in the calculation. (Fe = 56.)

3. Coal consists chiefly of carbon associated with smaller quantities of hydrogen, oxygen, nitrogen, and sulphur. Explain what becomes of each of the constituents (1) when coal is burned on a fire, (2) when it is distilled in retorts.

4. What is meant by the terms oxidation and reduction?

How do chlorine and nitric acid act as oxidising agents?

5. Fluorine, chlorine, bromine, and iodine are said to form 'a chemical family': point to the facts on which this statement is based.

6. What are the products obtained when carbon is heated with each of the following substances: (*a*) sulphur, (*b*) oxide of iron, (*c*) metallic iron, (*d*) arsenious oxide, (*e*) potassium nitrate, (*f*) sulphuric acid, (*g*) sodium carbonate.

7. What gases and solid substances are to be found dissolved in drinking-water, and how do they get into the water?

8. Mention some of the properties by which ozone can be distinguished from oxygen. How is it possible to explain these differences?

9. What are the sources, composition, and properties of some of the principal compounds of silicon?

COLLEGE OF PRECEPTORS.

Incorporated by Royal Charter.

Besides examining elementary schools this college undertakes to examine candidates for the various professions, and its certificates are accepted as evidence of a sound general education, amongst other bodies, by the Incorporated Law Society, the Colleges of Physicians and Surgeons, and the Pharmaceutical Society. The principal Examination is known as the 'Professional Preliminary Examination.' Chemistry in this Examination, as well as in the Pupils' Examination, is only an optional subject, and no practical work is set. No schedule of any kind is issued; previous examination papers serve to guide both examiners and examinees.

PROFESSIONAL PRELIMINARY EXAMINATION.

CHEMISTRY.

1. What is *common salt*? How is it decomposed by sulphuric acid? Show by symbols what are the products of its decomposition.

2. To prepare cupric oxide, metallic copper is burnt; and to obtain water by synthesis, cupric oxide is heated in hydrogen. From 100 grams of copper how much cupric oxide can be obtained; and how much water from the cupric oxide? ($H = 1$, $O = 16$, $Cu = 63{\cdot}3$.)

3. Define the terms *oxidation, reduction, burning, chemical combination, decomposition, electrolysis, synthesis, analysis,* and give examples, by equations or otherwise.

4. From what compound is phosphorus obtained? Show by equations how it is prepared, and how it combines with chlorine and oxygen.

5. A gram of carbon is completely consumed; what is the product? How much does the product weigh, and what is approximately its volume at the normal pressure and temperature? ($H = 1$; 1 litre of H weighs ·0896 gr. at 0° and 760 mm.; $O = 16$; and $C = 12$.).

6. How is sulphuretted hydrogen prepared? What is it used for? Is it combustible? if so, what are the products of its combustion? Is it respirable, soluble, coloured or colourless, lighter or heavier than air?

7. When horn, quills, or feathers are heated in a test-tube, a pungent gas, which turns red litmus blue, is evolved: how may it be prepared pure? What is its composition? What action has it upon hydrochloric and sulphuric acids? What is its chief source?

PUPILS' EXAMINATION.

CHEMISTRY.

I.

1. State precisely what you have seen take place when potassium and sodium have been thrown into water, and give the equation expressing the chemical change.

2. How can iron be made to decompose water? Give the equation for this decomposition.

3. When sulphur burns in oxygen it does not increase the volume of the gas. What has become of the sulphur, and why is the volume unaltered?

4. There are 280 million tons of coal burnt in the world annually. What becomes of it?

5. Describe in words, and by equations if possible, two ways of making ammonia gas. Is the gas heavier or lighter than air? Is it incombustible or combustible? What action has it on blue and red litmus?

6. Complete the following equations:—

$$H_2S + Cl_2 =$$
$$CaH_2O_2 + Cl_2 =$$

or $CaO.H_2O + Cl_2 =$
$CH_4 + 2O_2 =$
$CO_2 + C =$
$Ca_3P_2O_8 + 2H_2SO_4 =$

7. When iron pyrites is carefully burnt, the reaction is as follows:—

$$2FeS_2 + 7O = Fe_2O_3 + 2SO_2.$$
$$Fe = 56,\ O = 16,\ S = 32.$$

Calculate the quantity of air required to burn a ton (2240 lbs.) of pyrites, reckoning the oxygen in the air to be 23 per cent. by weight.

Chemistry.

II.

[N.B.—*Not more than* EIGHT *questions to be attempted.*]

1. Define *clearly* the following terms:—*Symbol, acid, equivalence, compound radical, chemical equation, halogen.*
2. Give the chemical name, and also the formulæ, of the following substances:—*kitchen salt, sal-ammoniac, plaster of Paris, white lead, calomel, oil of vitriol.*
3. Describe two processes for obtaining chlorine. Describe its properties and uses.
4. What do you understand by allotropism? Describe the allotropic forms of the non-metallic elements.
5. What is the composition of ordinary atmospheric air? Describe experiments by which the presence of each of its constituents may be demonstrated.
6. What are the ordinary impurities of spring water, and how may they be detected?
7. What do you understand by *hard* and *soft* water? How could you ascertain the degree of hardness?
8. Explain, in words, the reactions expressed in the following equations:—

(*a*) $K_2CO_3 + H_2SO_4 = CO_2 + H_2O + K_2SO_4$;
(*b*) $H_4NCl + NaNO_2 = NaCl + 2H_2O + N_2$;
(*c*) $KNO_3 + H_2SO_4 = HKSO_4 + HNO_3$.

9. Name the chief elements which enter into the composition of (*a*) water, (*b*) air, (*c*) flint, (*d*) clay, (*e*) coal, (*f*) limestone.
10. What do you understand by combustion? Describe an experiment by which air might be burnt.
11. A sample of coal contains 84 per cent. available carbon and 6 per cent. available hydrogen: what weight of atmospheric air will be required to burn 1 cwt. of the coal?
12. In the course of an analysis, ·4865 gram of silver chloride was obtained from 1 gram of an alloy which had been dissolved in nitric acid: what percentage of silver did the alloy contain?

SCIENCE AND ART DEPARTMENT.

Inorganic Chemistry.

First Stage or Elementary Examination.

Instructions.

You are permitted to *attempt* only *eight* questions.
Whenever possible, you are to express the reactions in equations.
You are to give such numerical details as will show the mode of calculation.

$$K = 39{\cdot}1.\quad Cl = 35{\cdot}5.\quad O = 16.$$

1. Classify the following substances as elements and compounds: chalk, graphite, water, sulphur, iron, ammonia, oil of vitriol, chlorine, diamond, ozone. (8.)

2. How would you distinguish hydrochloric acid from nitric acid? Give the formulæ of the two acids, and describe the preparation of a salt of each acid. (13.)

3. Express in the form of equations the action of

(1) Heat upon mercuric oxide.
(2) Sulphuric acid upon common salt.
(3) Hydrochloric acid upon marble.
(4) Nitric acid upon copper.
(5) Steam upon red-hot iron. (13.)

4. By what experiments can you prove that the air contains $\frac{4}{5}$ of its volume of nitrogen? (9.)

5. How could you convert sulphur dioxide into sulphuric acid, and sulphuric acid into sulphur dioxide? (13.)

6. 100 cb.c. of air are passed over red-hot charcoal. How would you ascertain if the air was altered in volume, or had experienced any alteration in properties? (13.)

7. How many litres of oxygen gas, measured at 10° C. and 755 mm., can be obtained from 1 kilogram of potassium chlorate?

(1 litre of oxygen at 0° and 760 mm. = 1·43 gram.) (15.)

8. What is meant by the term allotropy? Describe the various allotropic modifications of sulphur, oxygen, and carbon. (10.)

9. How would you prepare nitrous and nitric oxides? Give equations for the reactions, and state how you would recognise these bodies. (11.)

10. Explain what is implied by the following terminations: *-ous*, *-ic*, *-ite*, *-ate*, and *ide-*, and give examples of their use. (10.)

11. How are the two oxides of carbon prepared, and by what tests may they be recognised? (12.)

12. Why is the flame of a taper extinguished in nitrogen gas, and why does it continue to burn in air? (9.)

Alternative First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

1. A glass of water is exposed to the air. In time the water disappears into the air. How do you account for this? How could you prove that there is moisture in air? (13.)

2. Air is passed over red-hot iron. What change does this cause in the air and in the iron? (9.)

3. How could you show that the gas obtained by dissolving marble in hydrochloric acid is also contained in the breath? (10.)

4. Two samples of water are given to you. One is a hard water, and the other is distilled water. Describe two methods of distinguishing between them. (13.)

5. What is vinegar? How is it prepared? Vinegar is poured upon washing-soda: what happens? (9.)

6. Ammonia is classed as an alkali. Why? Name some of the sources from which it can be obtained, and give its composition. (15.)

7. A piece of lead, a piece of copper, and some mercury are separately heated in a crucible over a lamp. Describe what occurs in each case. (11.)

8. From what substances can starch be obtained? Of what is it composed, and how does it behave when boiled with water? (13.)

9. Name some commonly occurring compounds of sodium. How can you show that chlorine is a constituent of common salt? (10.)

10. What substances are contained in flour? How can they be separated, and what essential difference is there in their composition? (12.)

11. What is meant by saying that a solution is saturated? How would you prove that no loss of weight occurs when a substance is dissolved in water? (8.)

12. What are the distinguishing characters of cast iron, wrought iron, and steel? What is iron-rust? (13.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.
You are only permitted to *attempt eight* questions.
Whenever possible, you are to express the reactions in equations.
You are to give such numerical details as will show the mode of calculation.

Mg = 24. Ca = 40. K = 39·1. S = 32. O = 16. H = 1. Na = 23. Cl = 35·5.

1. By what leading characters are the metals distinguished from the non-metals? (10.)

2. Explain what is meant by the atomic value or valency of an element, and arrange the following bodies according to their valency: iron, copper, platinum, phosphorus, lead, silicon, calcium, sodium, chlorine, zinc, bismuth, tin, sulphur, arsenic, and carbon. (12.)

3. How many tons of oil of vitriol containing 70 per cent. H_2SO_4 are needed to convert 100 tons of salt into salt-cake? (12.)

4. Calculate the vapour density of ammonium chloride. By experiment it is found to be 13·345. How do you explain the difference between the calculated and observed results? Can you give any experimental evidence in support of your explanation? Do you know of any other similar cases? (15.)

5. How can you estimate accurately the amount of carbonic acid in atmospheric air? What causes tend (1) to augment and (2) to diminish its proportion in air? (11.)

6. How could you distinguish a chlorate from a perchlorate; a phosphite from a phosphate; a sulphite from a sulphate; an arsenite from an arsenate? (12.)

7. How is hydrofluoric acid prepared? Explain its action upon quartz, glass, zinc, and sodium carbonate. (12.)

8. Calculate the formula of a body which has the following percentage composition:—

Magnesium	3·98
Calcium	13·28
Potassium	12·99
Sulphuric acid (SO_4)	63·77
Water	5·98
	100·00

(15.)

9. Describe the method by which metallic lead is obtained from galena. What compounds of lead and oxygen are known? How are they prepared from metallic lead? (11.)

10. What is aqua regia? What compounds are formed by its action upon gold and platinum? (11.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.
You are only permitted to *attempt six* questions.
Whenever possible, you are to express the reactions in equations.
You are to give such numerical details as will show the mode of calculation.

H = 1. O = 15·96. K = 39·03. Br = 79·76. Ag = 107·66.

1. Illustrate the value of isomorphism as a means of chemical classification. (13.)

2. An unknown quantity of potassium bromoaurate, $AuBr_3KBr$, on being heated, left 9·92451 grams of a mixture of metallic gold and potassium bromide. The mass, on being treated with water, left 6·18997 grams of gold. The solution of KBr required 3·38540 grams of silver for total precipitation by Stas's method, and afforded 5·89143 grams of silver bromide. These data afford three independent values for the atomic weight of gold, which you are required to calculate. (18.)

3. What is the evidence that the molecules of most of the elements consist of two atoms? Name the bodies whose molecules seem to consist of only one atom. (15.)

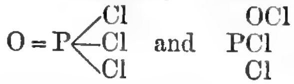
4. The following is an analysis of a sample of water:—

Total solids	4·4 grains per gallon.
Nitrogen, as nitrates and nitrites .	·017 "
Ammonia	·002 "
Albuminoid ammonia	·005 "
Chlorine	·800 "

Temporary hardness 0·1. Permanent hardness 2·4.
Total hardness 2·5.

Describe how such determinations are made, and give your opinion and the reasons on which it is based as to the suitability of this water for drinking purposes. (16.)

5. Phosphoryl chloride has been variously written



Which is the more probable formula, and why? (17.)

6. Give some account of the modern views of nitrification, and describe the nature of the experiments on which they are sounded. (17.)

7. What grounds had Mendelejeff for predicting the existence of the elements gallium, scandium, and germanium? (18.)

8. Describe the methods of determining by volumetric analysis the following substances:—Phosphoric acid, peroxide of hydrogen, nitric acid, and sal-ammoniac. (16.)

INTERMEDIATE EDUCATION BOARD FOR IRELAND.

The following shall be the subjects of Examination, viz.:—

Junior Grade.

Boys.

	Marks
(1) The ancient language, literature, and history of Greece	1200
(2) The ancient language, literature, and history of Rome	1200
(3) The English language and literature, and the history of Great Britain and Ireland	1200
(4) The French language . .	700
(5) The German language. .	700
(6) The Italian language . .	500
(7) The Celtic language and literature	600
(8) Arithmetic	500
(9) Bookkeeping	200
(10) Euclid	500
(11) Algebra	500
(12) Natural Philosophy . .	500
(13) Chemistry	500
(14) Drawing	500

Girls.

	Marks
(1) The ancient language, literature, and history of Greece	1200
(2) The ancient language, literature, and history of Rome	1200
(3) The English language and literature, and the history of Great Britain and Ireland	1200
(4) The French language . .	700
(5) The German language . .	700
(6) The Italian language . .	500
(7) The Celtic language and literature. . . .	600
(8) Arithmetic	500
(9) Bookkeeping	200
(10) Euclid	500
(11) Algebra	500
(12) Natural Philosophy . .	500
(13) Chemistry	500
(14) Botany	300
(15) Drawing	500
(16) Theory of Music . . .	500
(17) Domestic Economy . .	300

Middle Grade.

Boys.

		Marks
(1)	The ancient language, literature, and history of Greece	1200
(2)	The ancient language, literature, and history of Rome	1200
(3)	The English language and literature, and the history of Great Britain and Ireland	1200
(4)	The French language	700
(5)	The German language	700
(6)	The Italian language	500
(7)	The Celtic language and literature	600
(8)	Arithmetic	500
(9)	Euclid	600
(10)	Algebra	600
(11)	Natural Philosophy	500
(12)	Chemistry	500
(13)	Drawing	500
(14)	Theory of Music	300

Girls.

		Marks
(1)	The ancient language, literature, and history of Greece	1200
(2)	The ancient language, literature, and history of Rome	1200
(3)	The English language and literature, and the history of Great Britain and Ireland	1200
(4)	The French language	700
(5)	The German language	700
(6)	The Italian language	500
(7)	The Celtic language and literature	600
(8)	Arithmetic	500
(9)	Euclid	600
(10)	Algebra	600
(11)	Natural Philosophy	500
(12)	Chemistry	500
(13)	Botany	400
(14)	Drawing	500
(15)	Theory of Music	500
(16)	Domestic Economy	400

Senior Grade.

Boys.

		Marks
(1)	The ancient language, literature, and history of Greece	1200
(2)	The ancient language, literature, and history of Rome	1200
(3)	The English language and literature, and the history of Great Britain and Ireland	1200
(4)	The French language	700
(5)	The German language	700
(6)	The Italian language	500
(7)	The Celtic language and literature	600
(8)	Algebra and Arithmetic	700
(9)	Euclid	500
(10)	Plane Trigonometry	500
(11)	Elementary Mechanics	500
(12)	Natural Philosophy	500
(13)	Chemistry	500
(14)	Drawing	500
(15)	Theory of Music	300

Girls.

		Marks
(1)	The ancient language, literature, and history of Greece	1200
(2)	The ancient language, literature, and history of Rome	1200
(3)	The English language and literature, and the history of Great Britain and Ireland	1200
(4)	The French language	700
(5)	The German language	700
(6)	The Italian language	500
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(10)	Plane Trigonometry	500
(11)	Natural Philosophy	500
(12)	Chemistry	500
(13)	Botany	200
(14)	Drawing	500
(15)	Theory of Music	500
(16)	Domestic Economy	500

12. In the case of boys, no student shall obtain credit for the examination generally, nor shall his name be published in the Schedule of Results, unless he pass in at least four subjects, to each of which not less than 500 marks are

assigned, in which must be included one subject from each of the following groups, viz.:—

(A.)—(1) Greek; (2) Latin; (3) French; (4) German; (5) Italian; (6) Celtic.

(B.)—(1) Euclid; (2) Arithmetic; (3) Algebra; (4) Plane Trigonometry; (5) Elementary Mechanics; (6) Algebra and Arithmetic (Senior Grade).

In the case of girls, in all grades, it will be necessary and sufficient to pass in one subject from group (A), in English, and in any two other subjects of the Programme.

Junior Grade.

CHEMISTRY.

(Atomic weights, H = 1, O = 16, N = 14, Hg = 200.)

1. Nitric acid is added to:—(*a*) solution of indigo; (*b*) solution of litmus; (*c*) metallic copper; (*d*) solution of caustic potash. Describe the result in each case, and explain cases (*c*) and (*d*) by equations.
2. What evidence have we that air is a *mixture* of gases and not a chemical compound?
3. Given sodium carbonate and hydrochloric acid, how would you prepare a quantity of common salt?
4. Calculate the weight of oxygen obtainable by heating 432 grams of red oxide of mercury.
5. How is solution of ammonia obtained?
6. What are the chief properties of the substance which is represented by the formula NO?
7. What is meant by each of the following terms:—Analysis, synthesis, element, atomicity?
8. Describe an experiment illustrating the law of definite proportions.
9. Find the formula of the substance whose percentage composition is—

Hydrogen .	5·0
Nitrogen .	35·0
Oxygen .	60·0

10. Explain the action of plants in purifying atmospheric air.

Middle Grade.

CHEMISTRY.

(Atomic weights:—H = 1, O = 16, N = 14, K = 39, S = 32.)

1. Strong sulphuric acid is heated with (*a*) metallic copper; (*b*) common salt; (*c*) nitre. Explain the changes that occur in each case.
2. How would you ascertain the presence of *free iodine* in a solution?
3. Carbon dioxide is led (*a*) into lime-water; (*b*) into solution of caustic potash; (*c*) over red-hot charcoal. What is the result in each case?
4. How would you distinguish marsh-gas from hydrogen?
5. Crystals of a well-known salt are dissolved in water, and to the solution is added a solution of silver nitrate: the mixture remains clear. A fresh quantity of the crystals is strongly heated, the residue dissolved in water, and silver nitrate solution added; a white curdy precipitate forms, soluble in ammonia. What was the salt?
6. How is amorphous phosphorus obtained?
7. Name the three varieties of the element carbon, and compare their properties.
8. How could you demonstrate that ammonia gas contains nitrogen?
9. Calculate the weight of nitre that must be used in order to afford 10 grams of nitric acid.
10. How may it be shown, experimentally, that ozone is produced during the electrolysis of water?

Senior Grade.

CHEMISTRY.

1. What is the principle of Pattinson's process for the extraction of silver from argentiferous lead?
2. How would you distinguish *ferrous* from *ferric* chloride?
3. What is 'sugar of lead,' and how is it obtained?
4. Point out any exceptions to the rule that the molecules of elementary gases contain two atoms.
5. Give the formulæ of the following substances:—Limestone, white lead, chrome yellow, red lead, alum, magnetic oxide of iron, horn silver, washing-soda, butter of antimony, gypsum.
6. How is solution of caustic potash obtained?
7. What are the chief characters of metallic sodium?
8. What is meant by the term basicity of an acid? Give examples of mono-, di-, tri-, and tetra- basic acids.
9. How is liquid sulphur dioxide obtained?
10. What volume of air is necessary in order to burn completely one litre of carbon monoxide gas?

CIVIL SERVICE COMMISSION.[1]

CIVIL SERVICE OF INDIA.

4. The examination will take place only in the following branches of knowledge:—

		Marks
	English Composition	300
(c)	History of England—including a period selected by the candidate	300
(c)	English Literature—including books selected by the candidate	300
	Greek	600
	Latin	800
	French	500
	German	500
	Italian	400
(d)	Mathematics (pure and mixed)	1,000
	Natural Science: that is, the elements of any two of the following Sciences, viz.:— Chemistry, 500; Electricity and Magnetism, 300; Experimental Laws of Heat and Light, 300; Mechanical Philosophy, with outlines of Astronomy, 300.	
	Logic	300
	Elements of Political Economy	300
(e)	Sanskrit	500
(e)	Arabic	500

Candidates are at liberty to name any or all of these branches of knowledge.

No subjects are obligatory.

Owing to the changes recently made in the limits of age of candidates for the India Civil Service, it is probable that extensive alterations will shortly be made in these regulations.

CHEMISTRY.

1. Describe how to prepare hydrogen in quantity; how to remove from it traces of sulphuretted and arseniuretted hydrogen; and how to detect any admixture of nitrogen with it.
2. Explain how the proportion of the elements in carbon monoxide has been

[1] The Committee are indebted to Mr. W. A. Shenstone for special information respecting these examinations.

determined. What are the grounds for regarding the atomic weight of carbon to be 12 rather than 6?

3. With what different elements, and under what circumstances, will nitrogen unite directly? Show how ammonia may easily be obtained from each of the compounds so formed.

4. Describe the allotropic forms of phosphorus, and the circumstances under which they are formed. Show in what respects phosphorus resembles arsenic.

5. Illustrate, by at least three examples involving different reactions, the oxidising action of nitric acid, explaining the chemistry of each case.

6. Give an account of the chemical characters of iodine, hydriodic acid, and potassium iodide. How do you account for the reducing action of hydriodic acid?

7. 2·632 grams of a salt, containing only potassium, chlorine, and oxygen, gave when heated 851·2 cc. of oxygen gas; and the residual potassium chloride treated with silver nitrate gave 2·726 grams of silver chloride: calculate a formula for the salt.

8. Give an account of the chemical characters of lime. Compare them with those of the oxides of lead and magnesium.

9. Explain how malleable iron is made from cast iron.

10. Show that the chemical properties of the elements are connected with their atomic weights according to a definite law.

Practical Chemistry.

[N.B.—*In answering these questions be particular to state every experiment made in the order in which it was made, and to specify the reagents used in making it, and the effects which you observe to follow.*]

1. Make a qualitative analysis of the substance A.[1]
2. Examine with the blowpipe the substance B.[1]
3. Find the acid in C.[1]
4. Determine, by means of the standard solution of silver nitrate, the proportion of sodium chloride in the solution D.[1]

INDIA FOREST SERVICE.

The subjects of examination during recent years, and the marks assigned thereto, are detailed in the following table:—

	Maximum.	Minimum.
Arithmetic in all its branches	300	100 (with Compound Addition)
Compound Addition	50	
Orthography	300	150
Handwriting	200	100
Intelligence	100	—
English Composition	200	67
Algebra, up to and including Binomial Theorem	300	75
Geometry, including 1st, 2nd, 3rd, 4th, and 6th Books of Euclid	300	75
Plane Trigonometry	300	75
Elements of Mechanics	330	75
Elements of Physics	300	75
Inorganic Chemistry	400	80
Mechanical Drawing of Geometrical Figures	400	80
Translation from French	200	67
French, oral	100	33
Elements of Botany	400	80

[1] These substances were as follows:—

A. Litharge, B. Chrome-iron stone,
C. Sodium silicate, D. 5·005 grms. in four litres.

The above subjects are compulsory; but, in addition thereto, the annexed marks may be obtained in the following optional subjects:—

Translation into French	100
Freehand Drawing	300
Elements of Geology and Mineralogy . . .	300

From those competitors who attain the minimum amount of marks, and satisfy the requisite conditions in other respects, the Secretary of State will select those whom he may deem best adapted to the Service.

The candidates so selected will undergo a course of two years' special training at Cooper's Hill College, commencing with the annual session, which begins in September.

Under the new scheme which will come into force next year, the subjects of examination will be divided into three classes, namely:—

I. Obligatory subjects, in which a candidate must obtain one-third of full marks in order to qualify:—

	Marks
Lower Mathematics (as defined in prospectus) . . .	2,000
English Composition	1,000
German (400 for colloquial)	2,000

II. Optional subjects, of which a candidate may offer two, but not more than two:—

	Marks
Higher Mathematics (as defined in prospectus) . . .	2,000
French (400 for colloquial)	"
Latin	"
Greek	"
English History (as defined in prospectus)	"
Botany " "	"
Chemistry " "	"
Physics " "	"
Physical Geology and Geography (as defined in prospectus)	"

III. Additional subjects, either or both of which a candidate may offer:—

	Marks
Freehand Drawing	500
Geometrical	300

Elements of Chemistry.

1. Give an account of the composition and properties of the substance produced by burning sulphur in air.

2. What are the relative densities of oxygen, carbon dioxide, and water vapour, at the same temperature and pressure? Explain by reference to general laws why in a mixture of such gases and vapour the most dense does not sink to the bottom.

3. Describe the chief characters of nitrogen, and show how to obtain pure nitrogen. How can you prove that ammonia contains nitrogen?

4. Describe and explain the preparation of nitric acid. Explain the action of strong, and of dilute, nitric acid on zinc.

5. What sort of substances can be removed from water by (1) filtration, (2) distillation? Given a sample of water, how could you test whether it had been distilled? How is water affected by having carbonic acid in it?

6. Explain how sodium silicate is made, and how a solution of silicic acid can be obtained from it.

7. What do you understand by neutral and acid salts respectively? Give examples of each kind. If a solution of sulphuric acid will dissolve 20 grams of calcium carbonate and no more, calculate the amount of sulphuric acid in the solution. ($O : S : C : Ca = 16 : 32 : 12 : 40$.)

8. State the chemical composition of alum, blue vitriol, epsom salt, potassium permanganate, and corrosive sublimate; and mention uses to which they are applied.

9. In what substances and states of combination is phosphorus chiefly met with in nature? How is red amorphous phosphorus made? Point out the differences between that and ordinary phosphorus, and show why they are not chemical differences.

10. Show in what respects iodine resembles chlorine, magnesium resembles zinc, and manganese resembles iron.

11. Explain the chemical effects of exposing to the weather iron, lead, zinc, and copper respectively. How is iron *galvanised*? Mention other methods of protecting iron, and explain them.

Practical Chemistry.

1. Examine the substances A[1] and B[1] when heated
   (1) alone in a glass tube,
   (2) with sulphuric acid.

Describe the effects observed, and draw such inferences from them as you can.

2. Analyse the substance C.[1] State exactly what you do to it, and what is the result of each test applied. In stating your conclusions point out on which of the reactions you rely for proof.

3. Test the substance D[1] for a phosphate. State what you do to it, what results follow, and what conclusion you draw.

ROYAL MILITARY ACADEMY, WOOLWICH.

Candidates for admission by competition will be required to pass—
1. A 'Preliminary' Examination.
2. A 'Further' Examination.

Further Examination.

The subjects of the Further Examination, and the maximum number of marks obtainable for each subject will be as follows, until the close of the present year. Afterwards the values of the subjects in Classes I. and II. will be assessed at 2,000 marks each (3,000 for Mathematics). Subjects 3 and 4 in Class I. will become alternative, whilst two subjects will be permitted from Class II.

Class I.

(1) Mathematics:—

Part I. Obligatory. Algebra; Euclid; Plane Trigonometry; Mensuration; Statics; Dynamics 3,000

N.B.—A thorough knowledge of each of the above branches of mathematics will be required.

Part II. Optional. Further questions and problems on the subjects of the Preliminary Examination; Statics; Dynamics; the Elements of Analytical Geometry; Conic Sections 3,000

(2) Latin 3,000

(3) French (600 for Colloquial) 3,000

(4) German (600 for Colloquial) 3,000

Class II.

(1) Greek 2,000

(2) English History:—

One general paper.

One paper limited to a fixed period of which notice will be given 2,000

[1] These substances were as follows:—A, potassium iodide with mercuric iodide; B, oxalic acid; C, ferrous ammonium sulphate; D, carbonate with fluoride of calcium.

(3) Experimental Sciences[1]—viz. (*a*) the elements of inorganic chemistry; (*b*) electricity, magnetism, heat and light . 2,000
(4) Physical geography and geology, chiefly economic . . 2,000

Class III.

(1) English composition tested by the power of writing an essay or letter 500
(2) Drawing, freehand 500
(3) Drawing, geometrical. 500

Of these subjects (in addition to the Obligatory Mathematics) candidates will not be allowed to take up more than four, exclusive of those in Class III., nor will they be allowed to take up more than one from Class II.; but they may, in addition, take up all the subjects in Class III. There will be a practical Examination on subjects 3 (*a*) and (*b*), and 4 of Class II.

Inorganic Chemistry.

1. Describe an experiment to show that sulphuretted hydrogen gas contains an amount of hydrogen which, if free, would have a volume equal to its own.

Under what conditions will sulphur and hydrogen unite to form sulphuretted hydrogen?

2. Give a short description of the manufacture of sulphuric acid (oil of vitriol). What is the composition of the so-called 'chamber crystals'?

3. 20 litres of air are led through baryta water and yield a precipitate of 0·5 gram of baric carbonate. What is the percentage by volume of carbon dioxide present in the sample of air?

[Barium = 137. Carbon = 12. 11·16 litres of hydrogen weigh 1 gram.]

4. What is the effect of heat upon the following compounds respectively:—

(*a*) Mercuric nitrate; (*b*) Ammonic nitrate; (*c*) Potassic nitrate?

Give equations for the decompositions which take place.

5. Describe the preparation of silicon fluoride, and give an equation to explain the chemical change which occurs in your process.

What action takes place when this gas comes in contact with water?

6. How does the ordinary yellow phosphorus differ from amorphous phosphorus? How may they be converted, the one into the other?

7. From what source is iodine generally obtained? Describe its preparation. How would you distinguish between a piece of iodine and a piece of graphite?

8. How much 'pyrolusite' (manganese dioxide) must be decomposed by heat to yield sufficient oxygen to convert 160 grams of sulphur into sulphur dioxide?

[Manganese = 55. Sulphur = 32.]

9. What is the action of zinc and hydrochloric acid on an aqueous solution of sulphur dioxide?

10. Explain the phenomenon known as the 'spheroidal state of water.' How is the boiling-point of a liquid affected by variations in the atmospheric pressure?

Practical Chemistry.

[N.B.—*In writing out the results you obtain you are expected to state every experiment in the order in which it was performed, and to underline the results which you rely upon to prove the conclusions you arrive at.*

*** *If you use symbols in writing out your results, marks will be deducted for any errors which occur in them.*]

1. Find the two metals present in the alloy A.[2]
2. Analyse the simple salts B[2] and C.[2]
3. Find the acid which is in combination with sodium in the compound D.[2]

[1] Subjects (*a*) and (*b*) are alternative; a candidate will not be allowed to take up both.

[2] These substances were as follows:—A, alloy of zinc and tin; B, lead nitrate; C, strontium carbonate; D, sodic hyposulphite.

CADETSHIPS, ROYAL MILITARY COLLEGE, SANDHURST.

Further Examination.

The subjects of the Further Examination, and the maximum number of marks obtainable for each subject, are at present as follows, but it is understood that the marks assigned to the various subjects in this examination will shortly be modified, so as to raise the value of the subjects in Class II.

Class I.	Marks.
(1) Mathematics—viz. algebra, up to and including the Binomial Theorem; the theory and use of logarithms; Euclid, Books I. to IV. and VI.; plane trigonometry, up to and including solution of triangles, and mensuration	3,000
(2) Latin	3,000
(3) French (600 for colloquial)	3,000
(4) German (600 for colloquial)	3,000
Class II.	
(1) Greek	2,000
(2) Higher mathematics, including analytical geometry; conic sections; differential calculus; statics and dynamics	2,000
(3) English history:— One general paper. One paper limited to a fixed period of which notice will be given	2,000
(4) Experimental sciences—viz. (*a*) the elements of inorganic chemistry; (*b*) electricity, magnetism, heat, and light	2,000
(5) Physical geography and geology, chiefly economic	2,000
Class III.	
(1) English composition, tested by the power of writing an essay or letter	500
(2) Drawing, freehand	500
(3) " geometrical	500

Of these subjects candidates will not be allowed to take up more than four, exclusive of those in Class III., nor will they be allowed to take up more than one from Class II., but they may, in addition, take up all the subjects in Class III. There will be a practical examination in subjects 4 (*a*) and (*b*) and 5.

INORGANIC CHEMISTRY.

1. Describe an experiment to show that sulphuretted hydrogen gas contains an amount of hydrogen which, if free, would have a volume equal to its own.

Under what conditions will sulphur and hydrogen unite to form sulphuretted hydrogen?

2. Give a short description of the manufacture of sulphuric acid (oil of vitriol). What is the composition of the so-called 'chamber crystals'?

3. 20 litres of air are led through baryta water and yield a precipitate of 0·5 gram of baric carbonate. What is the percentage by volume of carbon dioxide present in the sample of air?

[Barium = 137. Carbon = 12. 11·16 litres of hydrogen weigh 1 gram.]

4. What is the effect of heat upon the following compounds respectively:—

a. Mercuric nitrate; *b*. Ammonic nitrate; *c*. Potassic nitrate?

Give equations for the decompositions which take place.

5. Describe the preparation of silicon fluoride, and give an equation to explain the chemical change which occurs in your process.

What action takes place when this gas comes in contact with water?

6. How does the ordinary yellow phosphorus differ from amorphous phosphorus? How may they be converted, the one into the other?

7. From what source is iodine generally obtained? Describe its preparation. How would you distinguish between a piece of iodine and a piece of graphite?

8. How much 'pyrolusite' (manganese dioxide) must be decomposed by heat to yield sufficient oxygen to convert 160 grams of sulphur into sulphur dioxide?

[Manganese = 55. Sulphur = 32.]

9. What is the action of zinc and hydrochloric acid on an aqueous solution of sulphur dioxide?

10. Explain the phenomenon known as the 'spheroidal state of water.' How is the boiling-point of a liquid affected by variations in the atmospheric pressure?

Practical Chemistry.

[N.B.—*In writing out the results you obtain you are expected to state every experiment in the order in which it was performed, and to underline the results which you rely upon to prove the conclusions you arrive at.*

⁂ *If you use symbols in writing out your results, marks will be deducted for any errors which occur in them.*]

1. Find the two metals present in the alloy A.[1]
2. Analyse the simple salts B[1] and C.[1]
3. Find the acid which is in combination with sodium in the compound D.[1]

OPEN COMPETITION OF CANDIDATES FOR ENTRY AS ENGINEER STUDENTS IN HER MAJESTY'S DOCKYARDS.

The following will be the subjects of the Competitive Examination, and the maximum number of marks for each subject:—

Arithmetic		300
English—		
Handwriting	40	
Accuracy and Intelligence in Writing from Dictation	60	
Composition	100	
Grammar	150	
		350
French or German or Italian—		
Translation into English		150
Latin—		
Translation into English		150
[2]Very elementary Physics and Chemistry		100
Geography (including Physical Geography)		200
Algebra (up to and including quadratic equations)		300
Euclid's Elements (Books I. to IV. and Book VI., and the definitions of Book V.)		300
Freehand Drawing		100
Total		1,950

[1] These substances were as follows:—A, alloy of zinc and tin; B, lead nitrate; C, strontium carbonate; D, sodic hyposulphite.

[2] The Examination in Physics and Chemistry will be easy questions in—
Chemistry—Oxygen, hydrogen, nitrogen, carbon, the nature of combustion.
Physics—Mechanics, hydrostatics, pneumatics, electricity, and magnetism.

CHEMISTRY.

Ten questions may be attempted in Chemistry and Physics, of which not more than four may be selected from Chemistry, and not more than three from each branch of Physics.

A.

1. What are the meanings of the terms atom and molecule?
2. How is hydrogen obtained in a pure state, and what are its properties?
3. For what reasons is the chemical formula for nitric dioxide given as NO, while that of nitrous oxide is N_2O?
4. Give an account of the method of preparing nitric acid, and explain your answer by a chemical formula.
5. What are the principal constituents of coal gas, and how may their respective formulæ be used to compare their densities?
6. State the effect of heating each of the following substances, and give the formulæ for the reactions:—

i. Potassium Chlorate ($KClO_3$).
ii. Potassium Nitrate (KNO_3).
iii. Calcium Carbonate ($CaCO_3$).
iv. Potassium Nitrite (KNO_2).

APPENDIX.

Exercises illustrative of an Elementary Course of Instruction in Experimental Science. By Professor ARMSTRONG.

The scheme put forward in the report presented last year by the Committee sufficed to indicate the kind of instruction likely to inculcate habits of observing correctly, of reasoning from observation, and of setting new questions and obtaining answers thereto by experiment and observation: habits which it is now generally admitted are of great consequence in the struggle for existence, and which cannot be acquired except through training in the methods of experimental science. Nevertheless, it has been felt that detailed directions how to proceed were necessary for the use of the less experienced teachers, and that even those who fully sympathise with the proposals already made would welcome the more complete display of the system. I have therefore obtained the permission of the Committee to append the following suggestions to their report, in amplification of certain parts of the scheme already published.

It is obviously impossible to sketch more than a small portion of a complete programme of instruction; the portion now offered is that appropriate to the earliest stage in which quantitative studies can be engaged in: its study can be commenced by children of fair intelligence when 9 or 10 years old. It is an essential feature of the scheme that it has reference to common things, the object being to lead children to engage in the rational study of the objects which are daily brought under their notice.

Time to be devoted to Experimental Studies and Mode of Teaching.—Frequently during the past year the question has been put to me, 'How much time is to be devoted to such science teaching?' and complaint has been made of the difficulty of dealing with large classes of children, of keeping them employed, and of providing the requisite space and appliances.

The question as to time will ever continue to be put until the fundamental fallacy which hitherto has retarded the progress of experimental teaching in schools is discarded, viz. that sufficient training in a scientific subject can be imparted in the course of a term or two. This undoubtedly is the view entertained in the majority of schools—girls' schools in particular. It is well known, for example, that of the many hundred students who each year present themselves at the London University Matriculation examination, the vast majority have had but a *few months' coaching* in chemistry, mechanics, or physics, although they have had lessons in arithmetic and like subjects during the *whole period* of their school career. It was long a superstition that to pass in chemistry all that was necessary was to have read some one of the small text-books, and a very large proportion of matriculants have doubtless had only such preparation. The fact is that our schools hitherto have been all but entirely in the hands of those who have had a purely classical or mathematical training, and who have gained their knowledge by reading. Teachers thus trained cannot realise that the useful effect of science teaching is only attained when the instruction is carried out on entirely different lines; they cannot realise that *accurate experimenting* is the essential feature in the system; that knowledge gained by mere reading is and can be of little use, as in acquiring it the mental faculties which it is desired to exercise never become trained. It must be recognised by all who have charge of schools that, in order to secure the due development of those faculties which science teaching alone can affect, the instruction must be imparted *from the very beginning and during the entire period of the school career.*

If this be done, many of the difficulties hitherto encountered may disappear. Probably it will be found advantageous, at least in the earlier stages, rather than disadvantageous, to devote but a short time during any one lesson to actual experimental work. There is no doubt that far too much is usually attempted; that too many facts are brought under the student's notice in the course of the lesson, the result being a blurred mental picture destitute of sharp outlines. After considerable experience I am satisfied that it is difficult to proceed too gradually—it may almost be said too slowly.

The following two sets of instructions are given by way of illustration; it is not pretended that they are complete, nor is it suggested that the exercises should be worked through exactly in the order in which they are stated, or completed by all pupils; the teacher must determine which are suitable for the particular set under instruction.

Studies of Water and Common Liquids.

1. Make every effort to elicit from the pupils by question and answer all that *they* have noticed with regard to water. Induce them to take advantage of any opportunities the neighbourhood affords of observing water and its effects. Let them ascertain the area covered by the school-house roof and the amount of water which falls on it when it rains; institute systematic observations of rainfall and embody the data in arithmetical exercises. Call attention to the different yearly rainfall of different parts of the country, and point out the influence of hills and mountains; let

outline maps be coloured, so as to indicate the different rainfall of different districts.

2. Call attention to the geographical distribution of water, &c.; also to the work which it does in nature (cf. 'Geikie's Physical Geography,' 'Huxley's Physiography,' &c.), illustrating this part of the subject, especially at an inland school, by lantern photographic slides of ships, sea-coasts, Niagara Falls, &c. &c.

3. Call attention to the disappearance of water, *i.e.* the drying up of rain, the drying of clothes, &c., and lead the pupils to notice that this takes place most quickly in hot weather and in warm places; then let them pour water into a clock glass placed either over a saucepan in which water is boiled by a gas-burner (or petroleum or spirit lamp, if gas be not available), or in a small gas cooking-stove; they will see that the water evaporates, leaving a certain amount of *residue.* [At this stage experiment on the extent to which water evaporates out of doors and indoors under different conditions and at different times of the year by exposing water in weighed glass (crystallising) dishes about 4 inches in diameter, and weighing at intervals. Also call attention to the fact that in certain states of the weather things become damp, and that moisture is sometimes deposited on the windows in cold weather; then let the condensation be noted of a liquid indistinguishable from water, which occurs, for instance, when a closed flask filled with water and ice is exposed in a room. Let some seaweed enclosed in a muslin bag be hung up out of doors where it cannot be wetted by rain, and have it weighed daily. At the same time have the temperature, direction of the wind, and character of the weather noted. Later on have the dry and wet bulb thermometer read daily. Have the changes in weight of the seaweed and the dry and wet bulb thermometer readings represented by curves. Lead the pupils to contrast and discuss the results.] The experiment should then be repeated with a known quantity of water and a weighed glass dish, so as to determine the amount of residue; the character of the residue should be noticed. Discuss the origin of the water, and point out whence the residual matter *may* have come. Next, if a well water was taken, let a local river or pond water be examined in a similar way, then rain water, and, if possible, sea water.

4. Let an ordinary 2-oz. narrow-mouth stoppered bottle, having a nick filed down the stopper, be filled with each of the waters and weighed, and let the operation be repeated several times with each water, so that the *experimental error* may be ascertained; it will be found that the different waters, sea-water excepted, have practically the same *density.* At this stage arithmetical exercises relating to the weight of known bulks, and *vice versâ*, of water, the quantities of dissolved solids present in given bulks of various waters, &c. &c. may advantageously be set; these should be solved practically by actual measurement in as many cases as possible.

5. Next ask, 'But what becomes of the water when driven off by heat?' If it have not been noticed that water collects (condenses) on some object near at hand, let a cold object be held over boiling water, then let water be boiled in a glass flask connected with a glass condenser. Afterwards have water distilled in larger quantity from a tin (2-gallon) can. The density of the distilled water should then be determined and its behaviour on evaporation. Data would thus be accumulated rendering it possible to explain the drying up of water under ordinary con-

ditions, the origin of rain, the differences between waters from various sources, and the method of separating water from the associated foreign matters will have been brought home to the minds of the pupils.

6. As the water is heated to boiling in the flask, if attention be paid to all that occurs, it will probably be noticed that bubbles separate from the water, rising up through it and escaping at the surface; frequently the bubbles adhere for a time to the flask. Let the experiment be repeated in such a way that the something which escapes from the water can be collected and measured; for example, a 2-gallon tin can having been filled with water, insert into the neck a rubber cork through which a bent *delivery tube* is passed, place the can over a burner, introduce the upturned end of the delivery tube into a basin of water, and insert a small jar over it. Heat to boiling. An air-like substance will gradually be driven off, but it will be noticed that after the water has been boiling for some time it ceases to give off gas; let the amount of gas collected be measured, and have the experiment repeated several times. As the gas does not continue to come off on boiling the water, it would seem that it is not a part of the water—there is so little of it, but merely something dissolved in the water; it is like air, and the water had been in contact with air—may it not be air? Let the boiled water be poured out into a galvanised iron pan, and after it has been exposed to the air for several hours let it be again boiled. The water which previously no longer gave off gas will now yield probably as much as before. It will thus be discovered that water dissolves air as well as the solid matters with which it comes in contact, and the presence of air in water will be recognised. This knowledge will be of value later on when the existence of animals and plants under water comes to be considered.

7. Attention having thus been directed to the solvent action of water, let special experiments be made on its solvent action, using salt, sugar, suet, washing soda, alum, tea and coffee, field or garden soil, clay, chalk or limestone, gypsum, &c.; known quantities of the filtered solutions should be evaporated to dryness, and the residues dried (conveniently in a small gas cooking-oven) and weighed. Opportunity will be afforded to call attention to the separation of some of the substances from solution in definite shapes, *i.e.* crystals; show these under the microscope as well as home-made cardboard models of some of them. Let larger crystals of alum be grown, and call attention to sugar crystals. Natural crystals of calcite, gypsum, pyrites, quartz, fluorspar, &c. would be appropriately shown at this stage. The question may then be put, Does the water which passes through the body dissolve anything? By evaporating urine and determining the amount of dried residue it would be found that a good deal of matter passes away from the body in solution.

8. Having directed attention to the different behaviour of different waters with soap, let determinations be made of the amount of alcoholic soap solution required to produce a lather in distilled and other waters. Directions for performing the soap test are easily obtained from a book on water analysis, and the operation is one of extreme simplicity.

9. Other liquids should now be compared with water, such as methylated spirit, turpentine, petroleum, salad oil, vinegar, and perhaps the common acids—muriatic, nitric, and sulphuric—also. The noticeable differences between these and water—appearance, odour, taste in dilute solution—having been registered, their relative densities should be determined; also their behaviour towards water and towards each other, their

behaviour when heated on the water-bath in comparison with that of water, their behaviour when burnt, their behaviour when boiled together with water in a flask attached to a condenser, and their solvent action in comparison with that of water should be ascertained.

10. Having given an account of the origin, &c. of the various liquids examined, and having alluded to the presence of alcohol in beer and wine, demonstrate the separation of alcohol from beer by distillation; then describe the production of alcohol by fermentation and carry out the experiment, first with sugar and yeast, then with malt; explain that yeast is an *organism*, and show it under the microscope and lantern photographs of it. Make several mixtures of alcohol and water and let the relative density of each be determined; then exhibit a table of relative density of spirit solutions of various strengths. Let a measured amount of beer be distilled, have the distillate made up with distilled water to the bulk of the beer taken and let its density be determined; reference being then made to the table of relative densities, the strength of the alcoholic distillate could be ascertained, and thus the amount of alcohol in beer would be determined.

11. The behaviour of water when heated may now be further studied; attention having been called to the thermometer as an instrument which enables us to judge how hot or cold it is, water should be heated and the gradual rise of the mercury column noted and the steady position which it assumes when the water boils. In the same way boiling water should be allowed to cool and the fall of the mercury column noted; further cooling should then be effected by means of ice, so that opportunity might be given for the stationary position to be observed which the column eventually takes up and maintains so long as unmelted ice is present. Having specially directed attention to these 'fixed points,' describe the construction of the thermometer. Next let a quantity of water be distilled from a flask or can having a thermometer in its neck, and let the steady position of the mercury throughout the distillation be observed. Also let water be frozen by means of a mixture of ice and salt; the 'temperature' of the freezing mixture having been ascertained, the thermometer bulb should be inserted into the water which is being frozen (in a test tube), so that the ice may form around its bulb: the temperature should be noted during freezing and also during the subsequent melting of the ice. Do this out of contact with the refrigerating mixture.

12. Let the relative density of ice be determined, *i.e.* after showing that although 'lighter' than water ice is 'heavier' than turps, let a cylinder partly filled with turpentine be counterpoised, and after the temperature has been lowered by immersing the cylinder in ice water, note the position of the turps, then introduce a few pieces of dried ice, note the rise of the turpentine—thereby determining the volume of the ice—and subsequently weigh in order to ascertain the weight of ice introduced. Have the result thus obtained checked by subsequent observation of the bulk of water which results when the ice melts. The expansion of water on freezing having thus been observed, the bursting of pipes in winter may be explained; and attention may also be directed to the destructive effects on rocks produced by the freezing of water; the extent to which ice floats may be discussed, and arithmetical problems may be set which will lead the pupils to realise the extent to which the volume changes when water changes its state.

13. Let the relative density of water and the other liquids be determined at 0° C. and at a higher temperature—that at 0° by weighing and

that at the higher temperature by observing the expansion of the liquids in bulbs with graduated stems of known capacity; let curves be constructed showing the relation between temperature and volume.

14. Let spirit, turpentine, petroleum, and vinegar be distilled; the temperature during distillation being observed, the gradual rise especially in the case of spirits and petroleum will be noted. Fractionally distil several times some quantity of spirit and of petroleum; let the relative density of each separate fraction be determined, and let the water separated from the spirit be characterised by freezing it and determining the melting-point of the ice and the boiling-point of the liquid which results when the ice melts.

15. Having directed attention to the fact that heat is 'used up' in melting ice and boiling water, let determinations be made of the amounts, following 'Worthington's Practical Physics,' for example.

Studies of Chalk and other Common Solids.

1. Call attention to the use made of lime in building and its production from chalk or limestone; slake a lump of lime; exhibit specimens and pictures of chalk cliffs or quarries and limekilns—if not to be seen in the district. Point out on a geological map those parts of the country in which chalk occurs, and those where limestone is met with. Explain how chalk is supposed to have been formed and show pictures of the forms which are present in it, and, if possible, microscopic slides. Explain that whitening, which is purchasable everywhere, is but lævigated chalk, describe its preparation, and let chalk and sand be separated by lævigation.

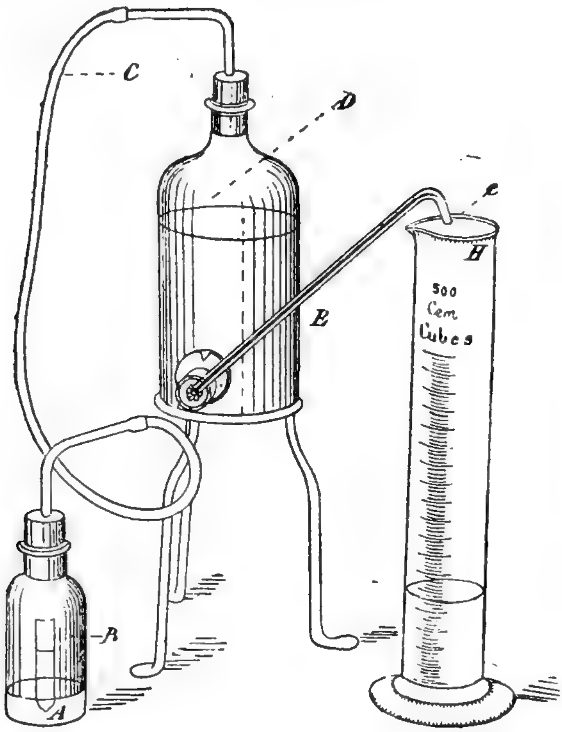
2. Let the conversion of chalk into lime be studied quantitatively. For this purpose three to five grams of dried whitening should be weighed out in a small platinum dish and heated to full redness in the *covered* dish during an hour over a Fletcher Argand Bunsen burner: the dish is then removed from the burner, and after about ten minutes, when cold, is weighed; it is then again heated, say for half an hour, &c.; usually there is no further loss. Several experiments should be made in this way, so that it may be noted that practically the same percentage of loss is incurred and the same amount of lime obtained in each case; and similar experiments should be made with chalks from different localities (Note A).

3. At the conclusion of each experiment, the residue should be carefully moistened with distilled water and the effect noticed; usually the lime slakes, becoming hot—some limes, however, slake very slowly, and the heating is imperceptible. The excess of water should then be driven off by heating in a water-oven until the weight no longer diminishes.

4. In comparing the solvent action of the various liquids previously studied, it will probably have been noticed that chalk is dissolved by acids—for example, vinegar or muriatic acid—with effervescence; such an acid may therefore be used, if necessary, in cleaning out the dish at the conclusion of the experiment if any of the solid adhere to it. Then, having made it clear that the effervescence is due to the escape of an air-like substance or gas, which is conveniently termed *chalk-gas*, let the amount of gas which is given off when the chalk is dissolved in acid be determined. For this purpose, the simple apparatus shown in fig. 1 may conveniently be used. From 1·5 to 2 grams of the chalk is weighed out on a small square of tissue paper, which is then folded up at the sides

and dropped into the bottle A, from which the tube B has been removed; a little water is then added (about 5 cubic centims.) and the chalk is shaken out of the paper; about 5 cubic centims. of nitric acid is now poured into the tube B, which is then carefully replaced in the bottle A.

FIG. 1.



The cork having been inserted, connection is established by means of the flexible tube C with the bottle D. The side tube E having been so adjusted that the end *e* is on a level with the water in the bottle D, the measuring cylinder H is so placed that any water which runs from *e* may be collected in it, and the bottle A is then carefully tilted so that the acid may gradually run out of the tube B into A; gas is at once given off and expels water from D. As the water sinks in D the side tube E is lowered so that its orifice remains about on a level with the water in D. The water is then measured. Several experiments should be made and the results should be compared by calculating the volume of gas which would have been obtained, supposing, say, 100 grams of the chalk had been dissolved.

5. In this way it is ascertained that *chalk-stuff* is *characterised* by (1) yielding between 56 and 57 per cent. of lime, which increases by about 33 per cent. when slaked; and (2) by yielding about 22,000 cubic centims. of chalk-gas per 100 grams when dissolved in acid.

6. Comparing lime with chalk, it is found that if the chalk be thoroughly burnt no gas is evolved on dissolving the recently slaked lime in acid; this result serves at least to suggest that the gas which is given off when chalk is dissolved in acid is perhaps expelled during the conversion of chalk into lime. The loss in weight which occurs is therefore determined, and when it is ascertained that it is very nearly the same as when chalk is burnt, no room is left for doubt that the same

substance is dispelled by heating and by dissolving the chalk in acid. The experiment is very easily carried out in a small bottle or conical flask provided with a tube to contain acid, and closed by a cork through which pass a narrow tube bent at a right angle and a small drying tube full of cotton wool. The chalk is weighed out on thin paper and dropped into the flask, a little water is poured on to it, and the acid tube is then introduced, after which the cork is inserted. The bent tube is closed by a small stopper. On tilting the flask acid escapes and attacks the chalk; the spray is prevented from escaping by the cotton wool. When the action is at an end air is sucked in through the narrow bent tube to displace the chalk-gas, and finally the loss in weight is determined. Such an apparatus gives admirable results.

7. Marble may then be examined in a similar way; as it is found to behave both on heating and when dissolved in acid much as chalk does, it may be presumed to consist of chalk-stuff. Next, limestones should be taken; the result obtained with them may be lower owing to their containing clay, &c.; but this is to a large extent rendered evident by insoluble matter left on treating with acid. Let the percentage of chalk-stuff in the limestones be calculated from the results which they afford, assuming the results obtained with chalk to be practically those afforded by pure chalk-stuff. Lastly, direct attention to the occurrence of crystals (calcite) in limestone rocks, to stalactites, &c.; show specimens, and have them examined: the results will show that they also consist of chalk-stuff.

8. Having pointed out that chalk consists of shells, &c., of sea-animals, coral and shells of various kinds—oyster, cockle, limpet—should be given for examination; all these will be found to give results from which it may be inferred that for the most part they consist of chalk-stuff. Egg-shell and lobster or crab-shell in like manner will be found to yield lime when burnt, and to behave much as chalk does towards acid, but the presence of a certain amount of 'animal' matter will be evidenced by the blackening on heating and the insolubility of a certain proportion in acid.

9. Ordinary bone, gypsum, clay, and rocks other than chalk or limestone rocks are next given for study, in order that it may be discovered that the behaviour of chalk-stuff is peculiar and characteristic, and that there are many varieties of natural solids. Rough estimates of the amount of chalk in soil may be made by determining the amount of chalk-gas evolved on treating the soil with acid.

10. In a hard-water district the residue from the water will probably look more or less like chalk; its behaviour when heated with acid and when strongly heated should therefore be determined, and local boiler or kettle scale should then be studied as chalk was previously.

11. In this manner a large number of data will be accumulated which render it possible to discuss the origin of chalk; to explain the presence of chalk-stuff in water and its withdrawal from water by animals, &c.

The study of chalk in the manner indicated would make it possible for the student (1) to comprehend the principle of the method followed by chemists in characterising substances whereby they are led to discover distinct forms or species; (2) to realise not only that there are *compounds*, but also that such substances have a fixed composition; and (3) the entire difference in properties between a compound and its constituents would have been brought out most clearly by comparison of chalk-stuff with its constituents—lime and chalk-gas. The chalk studies, in fact, should serve to incite the student's curiosity, and should lead to further inquiries being undertaken as to the composition of other substances and the characters of their constituents, and as to the nature of other changes; and with regard to the method of undertaking inquiries into the composition of other substances, the important results obtained in the case of chalk by studying the *changes* which it undergoes would serve to illustrate the importance of studying change as a means of determining composition.

It cannot be denied that only well-informed, thoughtful teachers could give useful instruction in accordance with the foregoing schemes; but this is scarcely an objection. The amount of special training required to carry out the experimental portion would not, however, be great; and there is no reason why such instruction should not be given in schools where there is no special science teacher engaged—although the services of such a teacher would undoubtedly be necessary if instruction in accordance with the more complete scheme embodied in the report presented last year by the Committee were carried out in its entirety.

The suggestion that probably it will be found advantageous at least in the earlier stages, rather than disadvantageous, to devote but a short time during any one lesson to actual experimental work (cf. page 300) would be realised in practice if the experimental science lesson were associated with the measurement or practical arithmetic and drawing lessons; and it is difficult to imagine that this is not possible. Supposo a set of twenty-four pupils to be at the disposal of a teacher during an entire morning or afternoon in a room of sufficient size, properly appointed, and that they are set to work to carry out the experiments with chalk, described on page 304. Several—say six—might be told off to weigh out in platinum dishes the necessary quantities of whitening, and having then placed the dishes on Fletcher burners or in a muffle, they would return to their places; at the end of an hour they would remove the dishes, and after leaving them during ten minutes to cool would weigh them. To determine whether any change took place on further heating, they would reheat the dishes during say half an hour, at the expiration of which time they would, as soon as the dishes were cool, weigh them again. As soon as the first set of six had weighed out the chalk, a second set of six might be set to work in a precisely similar way if the necessary apparatus were available, or if not at some other exercise involving the use of the balance.

The nature of the experiments which each set were engaged in performing should be made known to the whole class, and all the data should be written up on a blackboard. Each pupil should write out an account of the experiments and of the results; opportunity would thus be given to compare the results of the six or twelve separate experiments. At the next lesson the two remaining sets of the class would carry out the same experiments. Each pupil would thus have the advantage of performing one or other of the experiments, and of knowing what results had been obtained by a number of fellow-students. If necessary, two pupils might be set to perform one experiment, care being taken that they took equal parts in it; and thus the whole class of twenty-four might complete the experiment or experiments in a lesson.

Those of the class who at any time were not actually engaged in carrying out the experiment might be occupied in other ways, *e.g.*, in measuring distances, in drawing figures of stated dimensions, &c., in determining areas, in determining relative densities, in working out arithmetical problems, or in writing out notes and answers to questions. It would not be difficult as the class progressed to devise an infinite number of problems and exercises, the data for which were derived from experiments performed by the class.

If only one such lesson were given per week, a single teacher and an assistant might deal with 240 pupils, or with half that number if each class had two lessons per week—a much better course; and, working on a similar plan, much useful work might be done even in the course of two hours.

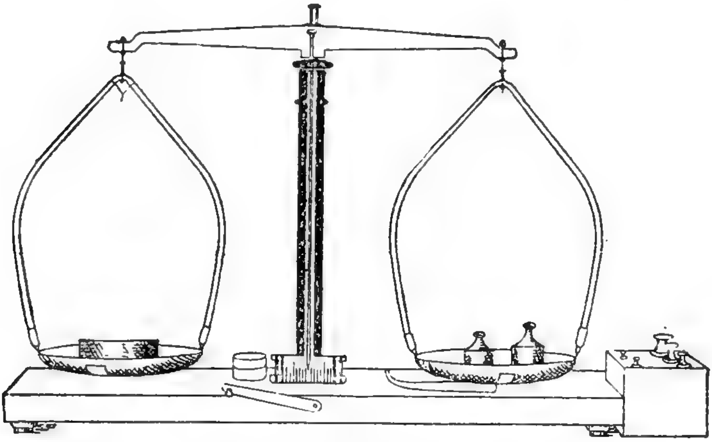
With regard to the appointments for such work, the school-room should be provided with simple working benches in addition to the ordinary desks and forms. A narrow table might be placed preferably across one end of the room on a raised platform, at which the teacher could sit and on which the balances could be placed; the teacher would then be able to supervise the weighing, and secure that due care were taken of the balances. A narrow bench (of deal, into which paraffin had been 'ironed,' so as to waterproof it) might be fixed against and along the wall at either side of the room. This should be fitted with simple cupboards and drawers for apparatus, and with gas taps if possible; and at a suitable distance from the wall and above the table there should be a bar, carried by brackets affixed to the wall, from which various apparatus, small scales, &c., could be suspended. A simple draught arrangement should and might easily be fitted at each working place, so that no unpleasant or noxious fumes need escape into the room. At the other end of the room it would be desirable to have a demonstration table, and behind this, against the wall, a draft closet at one end of a bench which has a capacious sink at the other end. It would be well also to have a sink within the closet, which could be made use of, for instance, in washing out a sulphuretted hydrogen apparatus. A muffle furnace at the side of the ordinary stove would be a most valuable adjunct.

The cost of carrying out experiments such as have been suggested remains to be considered.

The chief item is undoubtedly the balance. Useful work may be done at a very early stage of the measurement lessons with scales costing five or six shillings, as suggested by Professor Worthington, but their use for quantitative chemical work such as is comprehended in the foregoing scheme is entirely to be deprecated. The acquisition of the habit of weighing carefully and exactly is in itself a discipline of the utmost value, to which every boy and girl should be subjected. It is all important, therefore, that a fairly good balance should be used, and that the utmost care in its use should be enjoined. When not in use the balance should be covered over with a cardboard box. Becker's No. 51 (fig. 2) and No. 67 balances, to be had from Townson & Mercer, the English agents, are to be strongly recommended, the former being probably the more suitable as the pans are carried by 'bowed' wires, giving more room for manipulation, when, as in determining relative densities by the hydrostatic method, a bridge to carry a glassful of water is placed across the scale-pan. No. 51 costs 1*l.* 17*s.* 6*d.*; No. 67, 2*l.* 1*s.* A suitable set of weights (No. 31), from 500 grams downwards to centigrams, costs 18*s.* 4*d.* Even if six balances were provided—and such a number would suffice for a large class—the cost would be but 18*l.*

A convenient size of platinum dish to use is one about $\frac{3}{4}$ inch deep and 2 inches wide, weighing, with a light cover, about 20 grams. At a normal

FIG. 2.



price of platinum such a dish would cost about 25*s*, so that a considerable number might be provided for an outlay of 10*l.* Such dishes not only last a long time when properly used, but are of value when damaged (Note A).

A water oven for drying would cost about 1*l.*; one of Fletcher's small air ovens for drying costs 17*s.* 6*d.*

Fletcher's Argand Bunsen burners, with tripod, are to be recommended as superior to the ordinary burners for school work. The smaller size costs 2*s.*; the larger 3*s.* Suitable black rubber tubing for use with these burners, $\frac{3}{8}$ inch in diameter, costs about 9*d.* per foot. A pair of iron crucible tongs costs 1*s.*

The apparatus for measuring the gas evolved on dissolving chalk in acid would cost about 7*s.*, including a 500 cubic centim. measuring cylinder.

Glass basins about 3 inches in diameter cost 4*d.* each; clock glasses, 6 inches in diameter, 5*s.* per dozen.

50 cc. burettes cost 3*s.* 6*d.* each.

It is unnecessary to refer to the cost of the few remaining articles required for the suggested experiments, as they are well known. An expenditure of 50*l.* would certainly cover the cost of apparatus required by a class of, say, twenty-four, and which would suffice for the use of several such classes.

NOTE A.—The unfortunate rise in the price of platinum, which makes the purchase of any number of platinum vessels for school use out of the question, has led me to make a number of experiments in the hope of substituting silver; but, as was to be expected, this has proved to be impossible. I find, however, that porcelain may be used, provided that the heating be effected in a muffle furnace. Small thin hemispherical porcelain capsules may be obtained from the dealers, about the size of the platinum dishes specified, which are more suitable than porcelain crucibles for the experiment. Such dishes may also be used in studying the effect of heat on organic substances, the char being burnt in the muffle furnace.

Fourth Report of the Committee, consisting of Professors TILDEN *and* RAMSAY, *and* Dr. NICOL (*Secretary*), *appointed for the purpose of investigating the Properties of Solutions.*

THE Committee during the past year have continued the experiments on the Mutual Solubility of salts in water, and report as follows:—

The salts examined fall into two classes when arranged in pairs.

1. The solubility of one of the salts is affected to precisely the same extent by the addition of each successive portion of the other salts; as is the case with

NaCl	in solutions of	KCl,
NaCl	,, ,,	$NaNO_3$,
KCl	,, ,,	KNO_3,
$NaNO_3$	,, ,,	KNO_3.

Here, therefore, the salts share the water between them.

2. The solubility of one of the salts is not proportional to the amount of the other salt present, but is a steadily decreasing quantity in the case of

KCl	in solutions of	NaCl,
KNO_3	,, ,,	KCl,
$NaNO_3$	,, ,,	NaCl,

and a steadily increasing quantity in the case of KNO_3 in solutions of $NaNO_3$.

The Committee find that further experiments on the molecular volumes of the solutions are required before the work can be considered complete, and will at once proceed with these. They have also decided to examine the atomic volumes of carbon, hydrogen, and oxygen in organic substances when dissolved in various solvents. They therefore desire to be reappointed.

Fourth Report of the Committee, consisting of Professors TILDEN, M'LEOD, PICKERING, RAMSAY, *and* YOUNG, *and* Drs. A. R. LEEDS *and* NICOL (*Secretary*), *appointed for the purpose of reporting on the Bibliography of Solution.*

THE Committee report that considerable advance has been made with the work, which is now approaching completion. During the past year over 300 volumes have been examined, including the 'Chemical News,' the 'Journal of the Society of Chemical Industry,' the 'Journal of the Chemical Society,' Liebig's 'Annalen,' and the 'Chemical Gazette.' These contained 255 papers, bringing the total number of papers to 930.

The Committee have to thank Miss E. J. Lloyd and Mr. A. J. Cooper for their valuable assistance in carrying on the work. The Committee desire to be reappointed.

DISCUSSION ON THE THEORY OF SOLUTION.

[Ordered by the General Committee to be printed among the Reports.]

The present Position of the Hydrate Theory of Solution.
By SPENCER UMFREVILLE PICKERING, *M.A., F.R.S.*

IT is but four years since this Section devoted a day to the discussion of the nature of solution;[1] since then, however, the general aspect of the question and the position of the advocates of the two rival theories have undergone such a complete change, that in renewing the discussion we shall run but little risk of going over the same ground which we then trod. At Birmingham, Dr. Tilden opened the discussion by passing in review all the well-known and long-known facts which might by any possibility throw some light on the nature of solution, and those who followed him in the discussion each gave the interpretation of these facts which harmonised best with his own views, and, as the facts themselves were susceptible of several different interpretations, the not surprising result followed that each disputant departed holding precisely the same opinions which he had brought with him. Since then, however, each party has obtained, or thinks that he has obtained, positive evidence in favour of his own views; evidence which, if upheld, must be accepted as conclusive, or which must be overthrown before his opponents can claim the victory. The supporters of the hydrate theory claim that the curved figures representing the properties of solutions of various strengths show sudden changes of curvature at certain points, which are the same whatever be the property examined, which correspond to the composition of definite hydrates, and which, therefore, can only be explained by the presence of these hydrates in the solutions; while the supporters of the physical theory, now identified with the supporters of the osmotic pressure theory, claim to have shown that, with weak solutions at any rate, the dissolved substance obeys all the laws which are applicable to gases, and that, therefore, its molecules must be uninfluenced by, and uncombined with, those of the solvent.

In another respect also I may notice that our position to-day differs considerably from what it was four years ago; for instead of having to argue the matter out amongst ourselves, as we did then, we are now favoured with the presence of some of those whose work in this very subject has made their names familiar household words with every physicist and chemist throughout the scientific world.

I propose in the first place to give a brief summary of the evidence which has lately been adduced in favour of the hydrate theory, and in the second place to inquire whether the conclusions drawn from this evidence are invalidated by the important facts elucidated by Raoult, van 't Hoff, Arrhenius, and Ostwald.

In one respect the supporters of the hydrate theory start now under a distinct advantage, namely, that their most active opponents do not altogether deny the existence of hydrates in solution, although it is only in the case of strong solutions that they will admit their presence; in such solutions, indeed, it is difficult to see how their presence could possibly be denied. The only means which we have of proving that a liquid is a definite compound is by ascertaining whether its composition remains unaltered by its passage through the gaseous or solid condition—by

[1] *Report*, 1886, p. 444.

fractionating it by means of distillation or crystallisation. With liquids of comparatively small stability, such as hydrates, crystallisation is the only method available; the results of crystallisation have led us to conclude that the liquid represented by H_2SO_4 is a definite compound, and precisely similar results must force us to accept the definiteness of the liquids $H_2SO_4.SO_3$, $H_2SO_4.H_2O$, and $H_2SO_4.4H_2O$: in the case of each of them the liquid freezes as a whole, and without change of composition; the temperature remains constant throughout the solidification, and any excess of either water or sulphuric anhydride which may have been added may be separated from the pure compound, which alone crystallises from the mixture. Thus, in the instance taken, between the anhydride on the one hand and water on the other, we have four definite compounds, all existing in the liquid condition.

It does not follow, however, that every hydrate which exists in solution can necessarily be obtained in the solid condition; probably no solution, even when it possesses the exact composition of some existing hydrate, consists of that hydrate only, but of a mixture of it with the products of its dissociation (though the amount of these may be very small), and whether the hydrate or one of these dissociation products crystallises out on cooling must depend on the relative ease with which the bodies in question assume the solid condition; when the hydrate does not crystallise easily we can hope to obtain evidence of its presence by indirect means only.

Mendeléeff's conclusions respecting the densities of solutions of sulphuric acid and alcohol,[1] mistaken though I believe they were, led to the discovery of the means whereby such evidence might be obtained.

He stated that on plotting out the rate of change of the densities with the percentage composition of the solution (the first differential coefficient) he got a series of straight lines, forming figures with well-marked breaks at points corresponding to definite molecular proportions; but on plotting out the experimental points which he said formed these figures, it is impossible to see any justification for this statement; in the case of sulphuric acid the points and Mendeléeff's drawing of them have been given side by side in the 'Trans. Chem. Soc.' 1890, p. 81, and in the case of alcohol they will be found in the 'Zeit. f. phys. Chem.' VI. i. 10. Crompton then showed,[2] from an examination of Kohlrausch's values for the electric conductivity of sulphuric acid solutions, that a second differentiation might in some cases be necessary before rectilineal figures with breaks in them were obtained. In my own work on various properties of solutions of the acid I have made free use of this process of differentiation, but I have combined it with, and now nearly entirely rely on, an examination of the original curves with the help of a bent ruler.

In the 'Phil. Mag.' 1890, vol. i. p. 430, will be found rough sketches of the figures representing the densities, contraction on formation, electric conductivity, expansion by heat, heat of dissolution, and heat capacity of the solutions, and in the 'Trans. Chem. Soc.' 1890, p. 338, that representing the freezing points. In some cases, such as the freezing points of solutions near 58 and 100 per cent. strength, a mere inspection of the figure enables us to locate the position of abrupt changes of curvature; in general, however, the recognition of such changes is more difficult. On attempting to draw any of these figures with the help of a bent ruler it was found

[1] *Zeit. f. phys. Chem.* i. p. 275; *Chem. Soc. Trans.* 1887, p. 778.
[2] *Chem. Soc. Trans.* 1888, p. 116.

that the whole figure could only be drawn in several sections, and it was also found that each section thus drawn consisted of a single curve of a parabolic nature, although a ruler, when bent by the pressure exerted by the two hands, by no means necessarily forms a parabola; and, moreover—and this is the most important part of the evidence—it was found that these figures, though differing so greatly in their general appearance, all split up into the *same* number of sections, indicating the existence of changes of curvature at the *same* points; and, further still, these points corresponded to solutions of definite molecular composition in all cases where the ratio of the acid to the water was sufficiently large to render any such comparison possible; the average difference between the composition indicated by the changes of curvature and that of definite hydrates was only $0{\cdot}57H_2O$. With weaker solutions it is, of course, impossible to assert that the changes occur at definite molecular proportions, owing to the smallness of the change in percentage composition which would be caused by an additional molecule of water to each H_2SO_4; but the changes with these weak solutions are of precisely the same character as those with strong solutions, and, unless some strong evidence to the contrary be forthcoming, we must attribute them to the same cause.

To discuss fully the value of the evidence thus obtained would take me more hours than I can now afford minutes; but I think that I may say that these results stand at present unquestioned and uncontroverted, and that unless they can be controverted we must accept the presence of hydrates in solution as having been proved. I may also add that my results with sulphuric acid solutions have been strengthened by obtaining analogous results with solutions of several other substances: that one of the hydrates indicated by them has been proved to exist by isolating it in the crystalline condition: and lastly, that a law governing the freezing points of solutions has been formulated, according to which we can calculate within experimental error the freezing point of any solution, whatever its strength may be, provided we acknowledge the existence of every hydrate which my work has indicated; whereas, if we deny the existence of these, the freezing points calculated according to this or any other law show such divergences from the found values that all semblance of agreement disappears. I am indeed labouring under no small disadvantage in attempting to support the hydrate theory when the greater part of the evidence existing in favour of it is as yet unpublished.

Before proceeding to the second part of my subject I wish to draw attention to the great complexity of some of the hydrates which my work has indicated, as well as to the fact that the indications of sudden changes are nowhere more marked than they are with these very weak solutions. The changes, which are observed in the heat of dissolution curve from 5 per cent. downwards,[1] afford a good illustration of this latter fact; or, again, the freezing points of weak solutions may be instanced[2] where the rate of fall from 0 to ·07 per cent. is a quarter as great again as it is from ·07 to 1·0 per cent. The complexity of the hydrates indicated is so great that in the extreme cases they must be represented as containing several thousand H_2O molecules, and the suggestion of such complexity will no doubt prejudice many against my conclusions in general—though on what grounds I know not, for we

[1] *Chem. Soc. Trans.* 1890, p. 107. [2] *Ibid.* p. 343.

are entirely in ignorance at present as to the possible complexity of liquid molecules. It is interesting to note that a similar complexity of molecular grouping must be admitted if we accept Raoult's original statement that one molecule of any substance dissolved in 100 molecules of a solvent lowers the freezing point of this latter by about 0°·63; for, if this be so, we must assign to the molecules of the various substances entered in the second column of Table I. the magnitude there indicated when they are dissolved in the solvent named in the first column, for it requires that proportion of these bodies to lower the freezing point of 100 molecules of the solvent by 0°·63; and, amongst these few instances which I have collected from my own determinations, we find molecular aggregates containing as many as 200 of the fundamental molecules, and even this number, I may mention, probably understates the complexity to a very considerable extent; for the depression in this and some of the other cases had to be estimated from that observed with solutions containing as much as 10 gram molecular proportions to 100 of the solvent, and the molecular depression increased rapidly with the strength of the solution: $1000H_2O$ would probably be a low estimate of the complexity of the molecules of water when dissolved in a large excess of the hexhydrate of calcium chloride, a complexity comparable with that of the hydrates, which my other work has indicated, and that too in the case of that very substance which these hydrates contain—water.

TABLE I.—*Molecular Weights of Substances in various Solvents.*[1]

Solvent	Dissolved substance producing 0°·63 depression[2]
$100(H_2SO_4.H_2O)$	$32H_2O$
,,	$63H_2SO_4$
$100(H_2SO_4.4H_2O)$	$8H_2O$
,,	$15H_2SO_4$
$100([CaNO_3]_2.4H_2O)$	$90H_2O$
,,	$42Ca(NO_3)_2$
$100(CaCl_2.6H_2O)$	$210H_2O$
,,	$63CaCl_2$

Now as to the question of how far the theory of osmotic pressure, and the results on which it is based, are antagonistic to the hydrate theory: and let me first define clearly the position which I take in this matter. I do not for one moment call in question any of Raoult's classical work, which is now so familiar to us, nor do I question that these results reveal the existence of a depression of the freezing point which is approximately and generally constant; and I consequently admit that we can generally obtain an approximately correct value for the molecular weight of the substance by observing the depression which it causes; nor, again, do I wish to question the correctness of the mathematical relationship which van 't Hoff and Arrhenius have shown to exist between osmotic pressure, the lowering of the freezing point, and other properties, provided we accept the fundamental assumptions on which these calculations are based—the truly gaseous nature of dissolved matter, and the dissociation of salts into their ions. But what I do question is that the facts of the

[1] Other instances of high molecular weights are mentioned by Brown and Morris (*Chem. Soc. Trans.* 1888), and Gladstone and Hibbert (*Phil. Mag.* 1889, vol. ii. p. 38).
[2] Determined from the freezing points of very weak solutions.

case warrant such assumptions, or that the constancy and regularity of the results are so rigorous as to justify the conclusion that the solvent has no action on the dissolved substance, and that there are no irregularities such as would be caused by the presence of hydrates.

According to the osmotic pressure theory, the dissolved matter, so long, at any rate, as it is not present in greater quantity than it would be in the same volume of its gas, if it were gasified under normal conditions, is really in the gaseous condition, and obeys all those laws which apply to gases. According to the hydrate theory this will be but partially true. That the dissolved substance is in a condition comparable with that of a gas in so far as the separation of its own particles from each other is concerned, must be admitted—indeed, I arrived independently at this same conclusion from a study of thermo-chemical data—but inasmuch as there is present the solvent, which we believe is *not* an inactive medium, its molecules cannot have the same freedom as if they were truly gaseous, and will therefore obey the laws of gases imperfectly only.

It will be well to confine our attention to but one of those properties connected with osmotic pressure, and to select for that purpose the one which has been most fully investigated—the lowering of the freezing point of a solvent: and the tests which may be applied to ascertain whether in producing this lowering the dissolved substance behaves as a perfect gas or not, may be grouped under three principal headings :—

1. Is the molecular depression (*i.e.* that produced as calculated for one molecule dissolved in 100 molecules) constant, independent of the nature of the solvent ?

2. Is it independent of the strength of the solution, so long as this strength does not exceed the limits ('gas' strength) above mentioned ? (Boyle's law.)

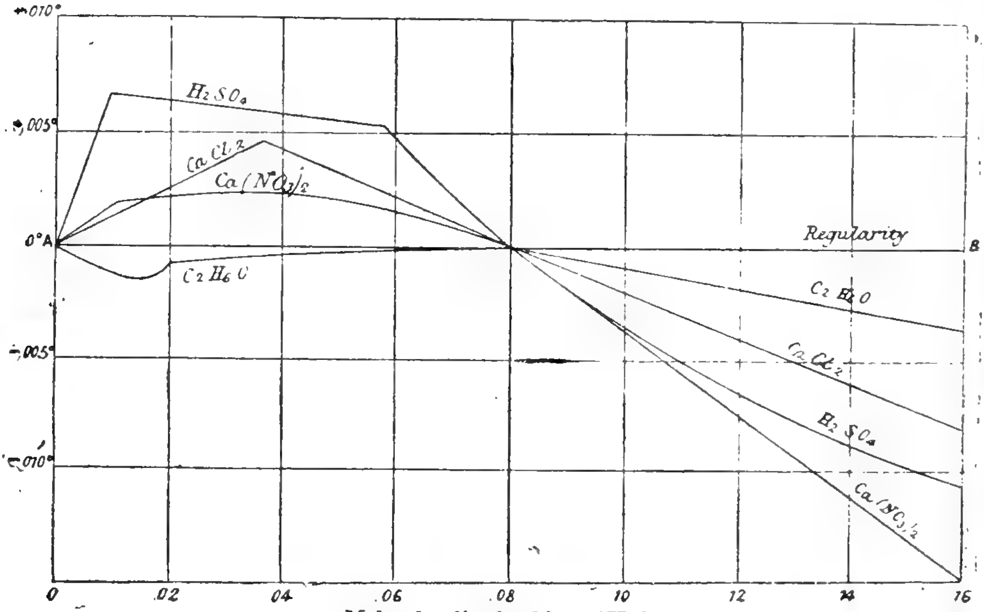
3. Is it independent of the nature of the dissolved substance ? (Avogadro's law.)

In the 'Phil. Mag.' 1890, vol. i. p. 495, will be found instances of the variation in the molecular depression which may be noticed by altering the solvent (see also Table I. above). With water in six different solvents it varied between 1°·072 and 0°·003 ; with sulphuric acid in four different solvents, between 2°·15 and 0°·01 ; with calcium chloride in two different solvents, from 2°·773 to 0°·01 ; and with calcium nitrate in two solvents, from 2°·5 to 0°·015 ; while many instances may be collected from Raoult's data showing that the same substance which acts normally in one solvent may act abnormally (give only half the usual depression) in another. Such variations are so great—from 100 to 35,600 per cent.—that there can be no doubt but that the solvent is *not* that inert medium which the supporters of the physical theory would have it to be, but that it has a very great influence on the results obtained. It must be noted, however, that this objection, though applying to Raoult's original views, does not, or, at any rate, may not, apply to van 't Hoff's theory, for, according to this theory, the nature of the solvent *has* an influence in determining the lowering of the freezing point, W, in van 't Hoff's equation, $\delta t = \frac{\cdot 02T^2}{W}$, representing the heat of fusion of the solvent. But the lowering is according to this equation independent of the nature or the amount of the dissolved substance, so that the two following objections will apply to van 't Hoff's theory as well as to Raoult's statement.

Secondly, as to the influence of the strength of the solution. It is remarkable that although the osmotic pressure theory depends on the behaviour of solutions below a certain strength, no attempt whatever has been made by its supporters to obtain any data respecting such solutions. The data on which their views were founded referred to solutions considerably stronger than the requisite 'gas strength,' and though, no doubt, it was convenient to work with data which afforded a ready excuse for any awkward irregularities which might be met with, such data must lack the conclusiveness which is so eminently desirable. The few data which I have accumulated as to solutions of an 'ideal' strength can leave no doubt that, even in their case, the depression is not a constant independent of the strength.

A solution of sulphuric acid containing $\cdot 08H_2SO_4$, $100H_2O$ would be of a strength comparable with the gas from the acid if it could be

FIG. 1.—Deviation from regularity of the freezing points of very weak solutions.



gasified at normal pressure and temperature, and the molecular depression should be constant for all solutions below this strength: it should be represented by a horizontal line such as AB in fig. 1, whereas the observed deviations from constancy are very great, being represented by the lines marked H_2SO_4; and, moreover, these deviations are by no means regular, and cannot therefore be attributed to imperfect gasification; they possess none of the characteristics of the deviations of gases from Boyle's law. The determinations on which these results are based are very numerous; there are about sixty experimental points on the portion here shown, and the mean error of each point as determined in two different ways was only 0°·0005, a quantity represented by one-tenth of one of the divisions of the paper; the deviations from regularity amount to thirteen times this quantity, and to as much as 16 per cent. of the total depression measured.

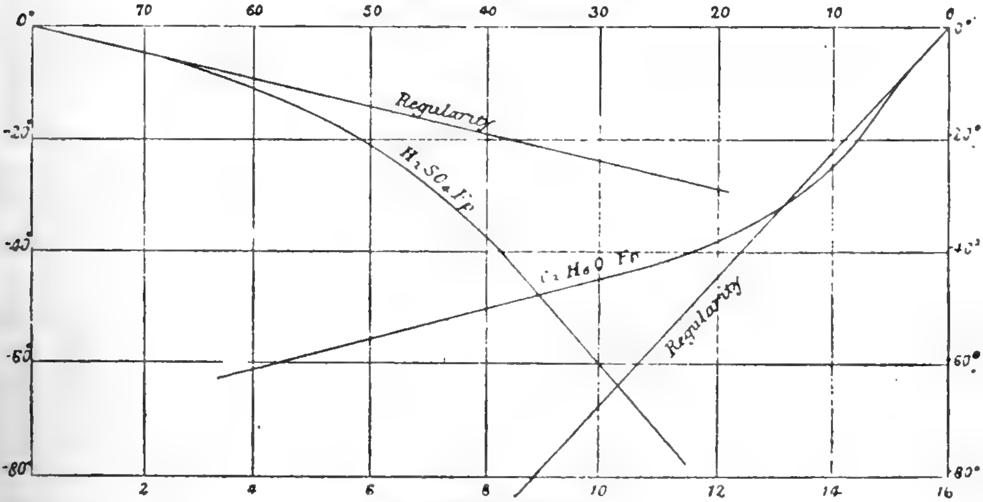
The other lines in fig. 1. represent the deviations from regularity in the case of calcium chloride, calcium nitrate, and alcohol respectively, and these, though they are smaller than in the case of sulphuric acid, are far too great to be attributed to experimental error; and the fact that they occur sometimes in one direction, sometimes in the other, precludes the possibility of attributing them to any constant source of error in the instruments used or in the method adopted.

Remembering that these are the only data which we have at present respecting very weak solutions, we must conclude that the hypothesis that such solutions exhibit perfect regularity is wholly untenable.

It is important to observe that when we pass on to stronger solutions, where the actual magnitude of the deviations becomes so great that they would be revealed by the roughest experiments—deviations of even 70°—and where, I believe, even the supporters of the osmotic pressure theory would not hesitate to attribute them to the disturbing influence of hydrates; these deviations occur in precisely the same irregular manner as they do in the case of weak solutions, and must evidently be attributed

FIG. 2.—Freezing points of sulphuric acid and alcohol solutions.

Mols. $(C_2H_6O)_2$ to $100H_2O$.



Mols. H_2SO_4 to $100H_2O$.

to the same cause. The results with alcohol given in fig. 2 illustrate these irregularities in a very striking manner. It must also be pointed out that, apart from the irregularity of these deviations, their very direction shows that they cannot be attributed to the dissolved particles being brought within the sphere of each other's attraction, as in the case of the deviation of gases from Boyle's law, for the result of this would be that their attraction on the particles of the solvent would be diminished and the freezing point of this latter would consequently be lowered to an abnormally small extent, whereas precisely the reverse is the case in nearly every instance at present investigated: the freezing points of strong solutions are abnormally *low*. Various instances of this will be found in the 'Phil. Mag.' 1890, vol. i. p. 500, that of sulphuric acid, which is illustrated here in fig. 2, being by no means the most prominent; while the case of alcohol, now for the first time displayed (fig. 2), is the only exception which has, so far, been met with, and that is an exception only in the case of excessively strong solutions.

From the instances above mentioned some answer may be obtained to the third question, whether the molecular depression is independent of the nature of the dissolved substance. The values obtained with these four substances, taking solutions of a strength corresponding to that of their gases, are :—

Calcium chloride	2°·850
Calcium nitrate	2°·744
Sulphuric acid	2°·313
Alcohol	2°·180

a variation of 30 per cent., which must give an emphatic denial to the idea of absolute constancy; and if we take instances from other substances, where the data available refer to solutions of somewhat greater strength, we find that the very substances on which the idea of constancy was originally founded show variations reaching 60 per cent. ('Phil. Mag.' 1890, vol. i. p. 492), while in other cases, which I have quoted elsewhere (*loc. cit.* p. 493),[1] the variation attains the still larger dimensions of 260 per cent.

To every one, therefore, of the three test questions as to constancy and regularity, the experimental results give an unhesitating negative.

In the instances quoted above the depression actually found for alcohol has been doubled in order to simplify the comparison of it with the other substances. Alcohol belongs to that class of bodies which give just half the value in water that the majority do, and of which there are some instances in the case of every solvent yet examined. The explanations which the supporters of the chemical and physical theories give of these half values differ so radically from each other that it is hopeless to attempt to arrive at any agreement as to the nature of solution till this difference is settled. The chemists say that these half values are in all cases the abnormal ones, just as Raoult did originally, and explain them by representing the molecules of the dissolved substances which give them to consist of two fundamental molecules. The physicists give exactly the same explanation in the case of every solvent except water, but in this case they say that the smaller values are the normal ones, and the larger the abnormal, the double magnitude of these being caused by the dissociation of the dissolved molecule into its two ions, whereby two molecules or acting units are formed from every one originally added.

If Raoult's views as to the consistency of the molecular depression can be maintained, the data themselves are conclusive against making this exception in the case of water; for, since the substances which give the lower values are supposed to act normally, it is evident that, if the values given are in any way abnormal, this abnormality must be due to the solvent. Now the values certainly *are* abnormal; they are about 1°·03, whereas the normal value for one molecule dissolved in 100 molecules of other solvents is 0°·63, and the excess can, therefore, only be explained by assuming that the molecules of water are more complex than those of other solvents in the proportion of 1·03 to 0·63, or $1\frac{1}{2}$ to 1; in other words, the water molecules must be $1\frac{1}{2}H_2O$. This view cannot be reconciled with the atomic theory.

Indeed the theory of dissociation into ions is altogether unintelligible to the majority of chemists. It seems to be quite irreconcilable with our

[1] The depression produced by H_2O in $100H_2SO_4$ is 1°·07 instead of 0°·07 as there given.

ideas of the relative stability of various bodies, and with the principle of the conservation of energy. Of course we know that each ion when dissociated is not supposed to be permanently dissociated, but to be continually combining with its neighbours and separating again from them as in every other case of dissociation; but at any particular moment a very large proportion of them is supposed to be free; a proportion which, according to the very results under discussion, must be very nearly, if not quite, 100 per cent. of the whole; and we have to settle whether it is probable or possible that a decomposition such as this could have been effected by introducing the compound into water. And how can we regard it probable that compounds of such stability and compounds formed with such a development of heat as sulphuric or hydrochloric acid should be thus entirely dissociated by water; still less that these, and all the most stable compounds which we know, should be thus demolished, while all the less stable ones—such as hydrocyanic, sulphurous, boric acids, &c.—remain intact? How can we admit that the more stable a body is, the more prone it is to be dissociated?

And if such a dissociation has occurred it must have been without any absorption of heat, and, consequently, energy must actually have been created. Take one of the simplest instances, that of hydrochloric acid. If anything at all is certain about atoms, it is that the atoms in an elementary molecule are united very firmly together, and that therefore in separating them a very large absorption of heat would occur. To separate 2HCl into 2H and 2Cl would absorb far more than the 44,000 cal. which we know are absorbed in separating 2HCl into H_2 and Cl_2. Yet the supporters of the dissociation theory would have us believe that this separation has actually taken place, not only without any absorption of heat, but actually with a development of 34,630 cal.; that is, that $44,000 + 34,630 + x$ cal. have been *created*, and that, too, through the intervention of the water, which has *ex hypothesi* no action whatever.

This difficulty is realised by the supporters of the physical theory, but the way in which they meet it does not appear to me in any way to overcome it. To explain the non-absorption of heat in the dissociation of the salt they suppose that charges of electricity combine with the liberated atoms, and in doing so evolve an amount of heat exactly equivalent to that absorbed in the separation of the atoms from each other; and a later development of this theory is, I believe, that the atoms, though separated, are still held together by means of these charges, so that the net result is the supplanting of the chemical bond by an electric bond of precisely the same value. It appears to me that nothing substantial is gained by such a substitution, and that its occurrence is not merely hypothetical, but impossible. Whence come these electric charges, and by what agency are they brought into play? On what grounds can it be maintained that a charge can combine with matter so as to evolve heat, and that the heat so liberated is exactly equivalent to that absorbed in the decomposition of the compound? And, if this equivalence exists, how can we account for the force which develops the one overcoming the *equal* force which develops the other? Or how, again, can we account for the heat developed in the act of dissolving? If, on the other hand, the heat of the combination of these charges is supposed to be equal to that of the combination of the atoms *plus* the heat of dissolution, we are met by the objection that the latter is often negative, and that therefore the heat of combination of the charges must often be *less* than that of the combination of the atoms and molecules, so that the lesser force must be regarded as overcoming the greater.[1]

That free ions exist in solution is supposed to have been proved by a recent observation of Ostwald's to the effect that these ions may be separated and brought into different parts of the liquid by the proximity of a charged body. The separation of the ions is, of course, recognised by the subsequent liberation of oxygen, hydrogen, acid, alkali, &c., and it is certain that, on allowing these to mix and combine, heat will be developed and the salt solution re-formed; and thus, by replacing and removing the charged body, it would evidently be possible to produce an unlimited amount of heat. Now, if the charged body has lost none of its charge, and if no mechanical energy has been expended, this heat must have been produced out of nothing, and the whole groundwork of physical science is false; whereas, if energy in some form has been expended on the solution, the experiment proves nothing, for there is nothing to show that this energy has not been utilised in bringing about that very dissociation the previous existence of which was in question.

I have already shown that the experimental data prove the absence of that constancy and regularity which ought to exist according to the physical theory, and to place the hydrate theory on unassailable grounds it is only necessary to show that the deviations from constancy and regularity are of a magnitude such as might reasonably be assigned to deviations due to the presence of hydrates. That variations of 260 and 36,000 per cent. in the value of the depression—such as are observed by altering the dissolved substance or the solvent respectively—are amply sufficient to satisfy the most exalted views of the influence of chemical attraction, requires, I think, no demonstration, and we may therefore content ourselves with examining the deviations observed when the proportions of the solvent are altered—such deviations as are illustrated in fig. 1.

It cannot be maintained that the energy of the chemical combination of, say, water with sulphuric acid, is the only reason why the temperature of the mixture of these two must be cooled below 0° before any of the latter will crystallise out; some lowering of the freezing point will be caused by the mere interposition of the foreign molecules of sulphuric acid between those of the water, and on certain grounds, which I have explained elsewhere,[2] I estimate this mechanical lowering, as I term it, at 0°·56 for each dissolved molecule to 100 of the solvent (a molecule of solvent water being $3H_2O$), a value which, it may be noted, is not far removed from Raoult's experimental value of 0°·63. There is also another source of lowering depending mainly on the heat capacities of the substances concerned, which I term for convenience the physical lowering; but its value, in the case of weak solutions, is very small, and I need, therefore, say no more about it here. Both these lowering causes would exist whether there were hydrates present or not; but if these were present we should get a further depression due to their existence. Any given hydrate would have to be decomposed into the next lower one before it could give up any water for crystallisation, and a certain amount of resistance would thus be offered to this crystallisation, to over-

[1] On the view that hydrates exist in solution, there is no difficulty, as I have shown elsewhere, in explaining the absorption of heat during dissolution, without violating the principle of the conservation of energy.

[2] *Proc. Chem. Soc.* 1889, p. 149.

come which the solution would have to be further cooled. The necessary cooling may be estimated in the following way: Supposing the solution to be a mixture and to be cooled below its normal freezing point; then, on solidification, the temperature would rise to this point; but if this solidification involved a chemical decomposition which absorbed x cal. the rise of temperature would be thereby reduced, the reduction thus caused amounting to $x \div$ the heat capacity of the solution. As the heat absorbed in the decomposition of the various hydrates of sulphuric acid is known, we can calculate the lowering produced by their presence.

TABLE II.—*Freezing Points of Solutions of Sulphuric Acid.*

I. Per cent. H_2SO_4	Calculated				VI. Found F. p.	Next hydrate	
	II. Mech.	III. Phys.	IV. Chem.	V. Total		VII. Calc.	VIII. Found
						Per cent.	Per cent.
·068	0·0209	0	·0110	0·0347 [1]	0·0354	0·37	0·36
·362	0·1114	·0004	·0248	0·1508 [1]	0·1582	1·43	1·06
1·06	0·3275	·0014	·0589	0·4314 [1]	0·4272	3·54	4·02
4·02	1·285	·071	·077	1·582 [1]	1·59	8·40	8·59
8·59	2·879	·388	·189	3·815 [1]	3·80	18·17	18·49
18·49	6·96	3·23	1·59	11·78	11·83	29·7	29·5
29·53	12·85	18·82	3·50	34·17	34·00	37·5	37·7

In Cols. II., III., and IV., Table II., I have given the depression due to the three above-mentioned causes in the case of certain solutions, Col. V. containing their sum; and it will be seen what a small proportion of this total lowering can be attributed to purely chemical causes. With most solutions it does not exceed 10 per cent. of the total, and with weak solutions, such as are generally used in freezing-point determinations—say 5 per cent.—it amounts to considerably less than 0°·1; this, too, in the case of sulphuric acid, where the heat of formation of the higher hydrates is greater than with any other known substance.

The reason, therefore, why the deviations from constancy are so small as to have escaped detection hitherto, and the reason why solutions behave almost as if their chemical nature was non-existent, becomes apparent; but this near approach to constancy and regularity, instead of proving the correctness of the physical theory and giving a death-blow to the chemical theory, is really one of the strongest arguments which can be adduced in favour of the latter. If the hydrate theory is right, the influence of hydrates must often be nearly inappreciable.

But it is not only a general concordance between the found and calculated magnitude of the irregularities which the hydrate theory is capable of affording, but a concordance so exact that the precise value of the deviation at any point may be calculated. In Col. VI. of Table II. are given the observed freezing points of the solutions, and these show an average difference of but 0°·004 for the three weaker solutions, and 0°·06 for the four stronger solutions, from those calculated (Col. V.). The last two columns exhibit this concordance in a different manner;

[1] The actual total has been increased by 10·4 per cent. of its value to give the figures quoted in these five cases, for reasons which will be given elsewhere. Some of the numbers in this table may be subject to slight corrections, as they have been quoted in the absence of the original calculations.

from the observed freezing point we can calculate the composition of the hydrates which must exist in the solution (Col. VII.), and these are found to agree so fully with those indicated by the examination of the curved figures representing various properties of the solution (Col. VIII.) that the maximum difference between the two is only 0·48 in the percentage of acid present.

When we can by simple calculations, based on one series of determinations, prove that the hydrates in solution must be the same as those which totally independent experiments have led us to suppose, we have, I think, arrived at proof as nearly absolute as it is possible to conceive; and, if I have succeeded in showing that this proof may be accepted without in any way rejecting the facts on which the advocates of the osmotic pressure theory rely—approximate constancy, approximate regularity, and approximate similarity between dissolved and gaseous matter—I shall feel that I have done far better work than the mere establishment of the hydrate theory, by pointing out a possible *modus vivendi* for both theories almost in their entirety, and by helping to break down that wall of separation between physicists and chemists which is fast crumbling into dust.

Dr. GLADSTONE made a communication on 'The Molecular Refraction of Substances in Solution,' in which he reconsidered the five reasons given in 1865 and 1869 for believing that 'the specific refractive energy of a solution is the mean of the specific refractive energies of the solvent and the substance dissolved.' In describing the present state of our knowledge, he brought forward some facts which have a bearing on the views under discussion.

In the first place, although it may be accepted as a rule that a solid when dissolved retains its former refractive power, it is a rule not without exceptions. Thus the experiments, both of the speaker and of Dr. Bedson, on rock salt agree in giving 14·6 as the molecular refraction of chloride of sodium for the solar line A or R; in which R represents the value $\frac{\mu-1}{d}$ multiplied by the molecular weight. But the molecular refraction for the same ray as calculated from aqueous solution is 15·3, showing that the water has perceptibly increased the refractive power. And this is not an isolated instance, for the observations of Topsoe and Christiansen on crystals of potassic bromide and iodide show a molecular refraction for the line D, or R_D, of 24·85 and 36·29 respectively, while the solutions indicate 25·7 and 36·9 respectively. In fact, the chlorides, bromides, and iodides in general, when dissolved in water, are known to exhibit a higher refraction and dispersion than would be calculated by adding together the generally received values for the metal and the halogen, and this increase is uniform for each series of salts.

It is also known that there is a slight change in the molecular refraction of certain liquid substances, such as acetic acid, when they are mixed with water.

In the second place the molecular refraction of a substance in solution is not varied by varying the amount of the solvent. In the case of water, however, there are some marked exceptions. With the hydracids the values increase with the dilution up to a certain extent, when they become stationary. Nitric and sulphuric acids are also exceptional. It is evident that the difference here noted does not depend upon whether these binary compounds are electrolytes or not.

In the third place there is a great deal of evidence that the molecular refraction of a substance is the same whether it be deduced from its solution in alcohol, ether, benzene, bisulphide of carbon, or any other solvent that does not act chemically upon it. The same rule applies in some instances to solution in water; thus the molecular refraction of ammonia in alcohol, or in different quantities of water, was found to be about 8·96. The value for gaseous ammonia, as deduced from Dulong's observations, is 8·60.

A notable exception is hydrochloric acid. Very early in the history of refraction equivalents it was recognised that this acid in aqueous solution gave a value much larger than the gas itself, or than what would be obtained by adding together the values for chlorine and hydrogen in combination, as deduced from other sources. Dr. Perkin found a similar great increase of magnetic rotation in an aqueous solution of hydrochloric acid, but on dissolving the gas in isoamyloxide and examining the solution he found it rotated the plane of polarisation to very little more than the theoretical amount. The speaker therefore determined the refraction of this solution, and found the hydrochloric acid in it to have practically the theoretical value.

HCl, theoretical value	11·2 or 11·3
HCl, in water	about 14·4
HCl, in isoamyloxide	11·36

It would not be safe to use this increase of refraction of hydrochloric acid in aqueous solution as an evidence either of dissociation or of the formation of a hydrate. For the sum of the molecular refractions of free hydrogen and free chlorine, as determined by Dulong or Mascart, would be only 10·3, rather less than the theoretical, instead of more, as might be expected on the dissociation hypothesis,[1] while, on the other hand, the addition value of H_2O in recognised hydrates (such as crystallised alums) seems to be the same as that of pure water, namely, 5·93.

The general inference drawn by the speaker from the accumulated evidence was that the old conclusion is substantially correct; that molecular refraction and dispersion may be safely deduced from substances in solution where the solvent is chemically inactive, but that in the case of water there is some profound change effected upon the constitution of hydracids, haloid salts, and probably some other compounds by the act of solution. What this change may be cannot at present be inferred from optical analysis.

Dr. JAMES WALKER read the following translation of a communication from Dr. ARRHENIUS:—

'In the "Journ. Chem. Soc." for 1890, p. 355, Mr. Pickering writes:— "It is indeed surprising that van 't Hoff, Arrhenius, and others should not have recognised that every known deviation from the so-called normal depression, when induced by increase of strength of the solution, is in exactly the opposite direction to that which it should be if the law of

[1] These numbers would have been brought more closely together if the calculation had been made by means of Lorenz's formula $\frac{\mu^2-1}{\mu^2+2}\times\frac{1}{d}$ instead of the simpler $\frac{\mu-1}{d}$. With liquids and solids it is practically unimportant which formula is employed.

osmotic pressure were really correct." That the depression of the freezing-point per gram-molecule should decrease with increasing concentration is no deduction (as Mr. Pickering seems to imagine) from the law of osmotic pressure; and the corresponding statement for the analogous case of highly compressed gases has been proved to be false by the researches of Regnault, Natterer, and others. . . . Besides, it is not correct that "every known deviation" is in the opposite direction to that expected by Mr. Pickering. From Beckmann's excellent determinations ("Zeitsch. f. physik. Chem." ii. 715) it appears that in the great majority of cases the molecular depression does diminish with increasing concentration when benzene and acetic acid are the solvents. Mr. Pickering can find numerous other examples in Eykman's observations, and I shall show below that it is even the case with the sulphuric acid solutions which were the subject of his own investigation. . . .

'Mr. Pickering, in comparing his "theoretical" with the observed values for the depression of the freezing-point in dilute solutions of sulphuric acid, remarks that "the molecular depression, *even in this extreme region*,[1] instead of being constant, as it should be according to the theory of osmotic pressure, varies between 2°·95 and 2°·1." Mr. Pickering has overlooked the fact that sulphuric acid is an electrolyte, and that the deviations may be accounted for by the theory of electrolytic dissociation. For the purpose of comparison with the experimental results, I have calculated the values of the depression for dilute solutions, such as Mr. Pickering investigated. In the calculation I have taken the freezing-point of an aqueous solution of a non-electrolyte containing one gram-molecule per litre to be —1°·90 C., in accordance with van 't Hoff's theory. I have further made the molecular conductivity of $\frac{1}{2}H_2SO_4$ at infinite dilution ($\mu\infty$) equal to $356/10^7$ Siemens' units (Kohlrausch, "Wied. Ann." xxvi. 196). From Kohlrausch's numbers we then find the degree of dissociation—

a for 1	·5	·1	·05	·03	·01	·006	·002	normal solutions
to be ·511	·533	·585	·658	·707	·802	·844	·910	

By interpolation we get a for other concentrations ("Zeitsch. f. physik. Chem." v. 5). From the percentage composition and the specific gravity (Pickering) I have calculated the number of gram-equivalents per litre solution. The subjoined table corresponds to that on p. 363 of the "Journ. Chem. Soc."

'Under obs.$_1$ are the (corrected) observed numbers obtained with thermometer 65,108; under obs.$_2$ are the numbers for the same concentrations interpolated from the series made with thermometer 65,561. This comparison affords an indication of the experimental accuracy.

'It is at once evident from the table that the observed numbers agree within the limits of experimental error (obs.$_1$ — obs.$_2$) with the theoretical values so long as the concentration is less than ·1 per cent. The agreement, in fact, is so extremely good as to lead one to put more faith in the calculated than in the observed values. In stronger solutions (1 to 4 per cent.) the depressions found are less than the theoretical depressions, in direct contradiction to Mr. Pickering's statement that the opposite is always the case. On this last circumstance, however, we need not lay too much weight, for the theory has not yet been sufficiently advanced in this direction, and the deviations besides only amount here to 3·6 per cent. at

[1] Mr. P.'s italics.

most. Instead, then, of these experiments of Mr. Pickering finally disproving "all existing physical [*sic!*] theories of solution," and in especial "the theory of osmotic pressure," they afford the most striking proof of the applicability of van 't Hoff's theory and the hypothesis of electrolytic dissociation to dilute solutions, with which alone these theories have hitherto been concerned.'

H_2SO_4 per cent	Sp. gr.	Gr.-equiv.	$i=1+2a$	Freezing-point			Differences in $\frac{1}{1000}$ deg. Cent.	
				Obs.₁	Obs.₂	Calc.	Obs.₁-calc.	Obs.₂-calc.
3·993	1·0278	·8376	2·036	$-1^{\circ}61$	—	$-1^{\circ}62$	−10	—
3·967	1·0274	·8324	2·036	1·58	—	1·61	−30	—
3·492	1·0243	·7300	2·042	1·37	—	1·42	−50	—
3·008	1·0210	·6267	2·051	1·19	—	1·22	−30	—
2·806	1·0193	·5835	2·058	1·10	—	1·14	−40	—
2·496	1·0174	·5182	2·064	·981	—	1·016	−35	—
1·996	1·0140	·4130	2·082	·788	—	·817	−29	—
1·785	1·0126	·3688	2·088	·705	·699	·731	−26	−32
1·596	1·0112	·3293	2·094	·633	·627	·655	−22	−28
1·398	1·0100	·2882	2·102	·558	·550	·575	−17	−25
1·212	1·0087	·2496	2·112	·484	·480	·501	−17	−21
1·024	1·0073	·2058	2·126	·417	·412	·416	+1	−4
·8188	1·0059	·1681	2·136	·334	·332	·333	+1	−1
·7138	1·0051	·1464	2·146	·297	·294	·298	−1	−4
·6145	1·0044	·1260	2·156	·255	·254	·258	−3	−4
·5146	1·0037	·1054	2·168	·219	·217	·217	+2	0
·4061	1·0029	·08312	2·210	·178	·177	·175	+3	+2
·3562	1·0025	·07288	2·236	·160	·155	·155	+5	0
·3063	1·0022	·06264	2·272	·138	·137	·135	+3	+2
·2594	1·0019	·05281	2·304	·115	·116	·116	−1	0
·2056	1·0015	·04203	2·352	·095	·093	·094	+1	−1
·1539	1·0011	·03144	2·406	·067	·072	·072	−5	0
·1401	1·0010	·02861	2·422	·062	·067	·066	−4	+1
·1012	1·0007	·02067	2·476	·052	·049	·049	+3	0
·0771	1·0005	·01574	2·544	·038	·035	·038	0	−3
·0519	1·0003	·01060	2·594	·026	·028	·026	0	+2
·0264	1·0001	·00539	2·702	·016	·014	·014	+2	0
						Sum .	+7	−10

Dr. WALKER drew attention to the fact that in almost all the combinations of solvent and dissolved substance tabulated electrolytic dissociation played a great part, entirely neglected by Mr. Pickering. The comparison of observed with 'theoretical' values was thus open to the same objection as Dr. Arrhenius urged in the case of dilute solutions of sulphuric acid, and so the great discrepancies found in the tables were from this cause alone rendered illusory.

Professor RAMSAY suggested that it might well be the case that complex molecular aggregates were capable of existence alongside of dissociated molecules where ions are present. In the case of solutions of sulphuric acid, for example, it is by no means inconceivable that aggregates of several molecules of sulphuric acid $(H_2SO_4)_n$, or of compounds of acid and water, such as $H_2SO_4.2H_2O$, &c., might exist along with the ions of dissociated sulphuric acid, 2H and SO_4, or more probably H and HSO_4. The abnormal results in the freezing-points of solutions of sulphuric acid observed by Mr. Pickering might well be due to some such cause.

Dr. ARMSTRONG, after remarking that thus far the physical aspects of the main problem under discussion—the constitution of solutions which conducted electrolytically—had alone been dwelt on, said that it would be impossible, in the time at disposal, to consider more than one of the conclusions arrived at by the advocates of the dissociation hypothesis, which did not appear to be in accordance with the chemist's experience. It had hitherto been customary to regard the neutralisation of an acid by an alkali as a case of interchange or double decomposition, as represented, for example, by an equation such as

$$KOH+HCl=KCl+HOH.$$

But now that it was argued that hydrogen chloride, potassium hydroxide, and potassium chloride underwent almost complete dissociation when dissolved in water to form a dilute solution, it became necessary to suppose that in such cases the only new compound formed in solution was water, and the main action which occurred on mixing solutions of potassium hydroxide and hydrogen chloride was consequently represented by the equation

$$H+Cl+K+OH=K+Cl+H_2O.$$

Such a conclusion, although undoubtedly a necessary and logical one from the dissociationist's point of view, involved the admission that hydrogen chloride and water were compounds of a totally different order; that these two hydrides were so different that while that of chlorine underwent practically complete dissociation that of oxygen remained practically unchanged. Chemists, however, were in the habit of teaching that chlorine and oxygen were comparable elements, and the facts of chemistry appeared to afford the strongest evidence that hydrogen chloride and oxide were in all ways comparable compounds. Moreover the behaviour of the two compounds at high temperatures afforded no grounds for any such belief in the instability of the one and the stability of the other.

Referring to the series of numerical agreements between theory and practice relied on by the dissociationists, the speaker said that in his opinion these afforded no necessary proof of the correctness of the theory. The correlation of chemical activity and electrical resistance which had been established by Arrhenius, Ostwald, and others was undoubtedly of the highest importance, but the successful use which they had made of the data at their disposal appeared to him to depend on the fact that by observations of electrical resistance they were enabled to classify electrolytes in the order of their activity, whether physical or chemical; and that, having done this, they were in a position to apply the correction required to discount the superior activity of such compounds in comparison with dielectrics, *i.e.* compounds producing the so-called normal effect in depressing the freezing-point, for example.

Professor FITZGERALD said:—It is important to distinguish between what is implied and what not by experiments: *e.g.* osmotic pressure, change of freezing and boiling points are in no way independent; we can deduce one from the other by applying known principles. There seems to be a very important connection, which cannot be deduced from known principles, between conductivity, the variation of osmotic pressure from its value calculated from molecular weights, and the chemical activity of a substance in certain relations. The quality upon which these properties depend is, I think, certainly the same quality in each case, and its existence and importance have been brought to light by the labours of our renowned visitors and their collaborateurs, and the discovery is one of the most valuable contributions to chemical physics that has been made of recent years. The visitors call this quality the 'ratio of dissociation.' Professor Armstrong would rather call it 'measure of affinity.' I would be inclined to point out that the term 'dissociation' is not happily chosen, and that 'affinity' really explains very little, and that it would be better to call it by a new name whose full meaning will require further investigation, and would call it 'measure of ionisation.'

In the first place as to the term 'dissociation.' In all other cases of dissociation, *e.g.* in an electric arc, the elements are so far free from one another that they diffuse independently of one another. The term 'dissociation' is no doubt vague, but it is time we had a more definite notion of it. I would certainly confine the use of the term to such cases that there was no link connecting the elements that would prevent their diffusing independently of one another. As long as there is any link connecting the elements of molecules together which essentially prevented one of them getting away without the others following, I would not agree to say that the elements were dissociated. Hence I object to the term dissociation as applied to the ions in an electrolyte. All agree that one cannot escape or diffuse without the other following; it may be due to electrical forces between them, it may be for other causes; but in either case I would refuse to call them dissociated. The possibility of independent diffusion I look upon as a test of dissociation. I would therefore appeal to both sides to adopt some neutral term such as 'ionisation' to express the state of ions in electrolytes. Now as to the proofs that the ions are absolutely independently mobile in the liquid, and the assumption from this that they are free like the molecules of a gas, being kept apart by the molecules of the solvent. This seems a very misleading way to speak of the condition. In the first place it is acknowledged that different solvents have different powers of ionising a given substance, thereby conclusively proving that the function of the solvent cannot be properly described as merely giving the ions space to resolve themselves. And those who speak so acknowledge that it is only an analogy, or a *façon de parler.* But it seems a very misleading analogy, which leaves out the really active part that the solvent plays, and attributes to it a purely passive part. The argument of van 't Hoff that the osmotic pressure in very dilute solutions depends only on the kinetic pressure, and not on the forces between the molecules, seems to cut against the conclusion that these forces must necessarily be small; it seems to show that, *whatever* forces there are between the ions, they will produce the right amount of osmotic pressure if only they are so far independent that each ion can carry on its bombardment independently of the other. As this only requires the space within which they are bombarding about to be small compared with the space rate of variation of the force between the elements, and as this is quite consistent with there being plenty of connection between the elements, it follows that the laws of osmotic pressure so explained do not in the least militate against there being bonds between the elements. The whole argument is, however, I think, fallacious, in that it assumes a particular theory as to the action between the semi-permeable membrane and the liquid. It would follow from this theory that one molecule of a salt could never produce osmotic pressure in its own neighbourhood by any forces of attraction between it and the solvent. Now if we apply this on a large scale to the case of an ocean

1,000 miles deep surrounding the world with a membrane in it, say, 100 miles deep, through which the water could go, but the world could not because the holes were only, say, about a square mile in area, we see at once that, if this membrane were made of a material lighter than water, *i.e.* less attracted by the world than water, it would tend to burst out with a great force, *i.e.* it would float out from the world because the pressure in the water near the earth was much greater than at a distance from it. This shows where van 't Hoff's argument fails. He has neglected the difference of pressure in the solvent near and far from the salt, or at least has assumed that this difference of pressure could not act upon his semipermeable membrane because the membrane is permeable to the solvent. It is, however, quite evident that the water can press very hard even on a membrane permeable to it, as is explained by the example I have just mentioned. Considering the complex nature of the problem, I think it is quite too soon to assume that the state of affairs assumed by van 't Hoff is at all like reality. I would much rather look for an explanation in the direction I have pointed out in this year's report of the Committee on Electrolysis. The argument there tends to show that the distances between molecules would arrange themselves so that the forces due to different kinds of molecules would be independent of their kind and depend on their numbers, and this would lead to the laws of osmotic pressure. It seems to me much more likely that a state of affairs such as I have supposed existing near the earth is the one existing in a liquid.

As regards the argument for the independent mobility of the ions founded on the laws of electrolysis, I think that just as in the case of osmotic pressure this does require a certain kind of independent mobility, but just as in that case I do not see that the required amount of independence cannot be attained without supposing a complete independence. There seems no doubt that conductivity and double decomposition are essentially connected with the same quality in the solution, and this property I have proposed to call 'ionisation.' Now, Williamson's hypothesis as to the nature of double decomposition and Clausius' as to the nature of electrolytic conduction only require that the ions shall be so far free as that they shall be frequently exchanging partners; neither hypothesis *requires* that they shall be during a finite time without partners, which I consider to be an essential condition of any right use of the term dissociated ions. If during the time the ions are paired they can move independently within the little chinks they have to move in between the molecules of the solvent—and be it observed that this is the same condition as for the extra osmotic pressure, *i.e.* if their chinks are small compared with the variation of force between the ions—then there seems quite sufficient independence for any theory of electrolysis, if, whenever two molecules were within the same chink, there were, as there would be, sufficient independence for an exchange of partners. Thus these two phenomena would be explicable upon the same hypothesis, and that without assuming that ionisation was a true dissociation. I have already explained that even those who insist most strongly upon the dissociation hypothesis yet guard themselves from its being supposed that this dissociation is an actually complete independence of the ions from one another. On all these grounds then I would appeal against the use of the word dissociation in this connection. Professor Ostwald says that there will result two theories leading to the same result. I dissent from this. The two theories are *essentially* the same. There have been unnecessary assumptions no doubt made as to how far an absolute independence of motion of the ions is required by the experiments, and I combat this unnecessarily absolute independence, but in all essential respects my theory is the same as the other. This unnecessarily absolute independence has been introduced in order to make what is acknowledged to be an 'analogy' appear as if it were more than an analogy, to give verisimilitude to what is at the same time said to be merely a *façon de parler*, to make what is known to be complicated appear unreally simple.

It may be worth while following Professor Armstrong's suggestions that the way in which the double decomposition is facilitated by a solvent is by the two salts entering into combination with the solvent and forming a large molecule. Then by a process of tautomerism [1] by which the elements within a molecule exchange places the double decomposition is effected. A similar but regulated rearrangement under electric forces would account for electrolysis. That solution is a true chemical combination seems undoubted. There is change of nature—*e.g.*, solid salt and ice change into liquid—redistribution of energy, change of volume, every change significant of chemical action; and that solution can be saturated shows that there is combination in definite proportions, even though some doubt may exist as to the existence of cryohydrates. In speaking of solvents as merely giving molecules space wherein to resolve themselves into ions, it seems as if the part of Hamlet were left out. The action of the solvent is to cause ionisation, some solvents do it and some do not, and it is rather hard on these strangely active solvents not to recognise this activity, one of the most wonderful and effective of all chemical actions known to us.

As regards the energy required for dissociation, or, as I would prefer to call it, ionisation, I agree with Professor Ostwald that any required supply can be obtained by assuming either an affinity of the element for electricity (a form of words I object to for reasons to be presently stated) or by supposing the ionic state to be an allotropic form of the atom with a different internal energy in it from that in the atom when in combination. The reason I object to the term affinity of the atom for electricity is that all we know of electricity seems to show that if any body attracts positive electricity it repels negative, and in that case the atom and its electrical charge combined would not be acted on by electrical forces as is required in order to explain electrolysis. I do not like the idea of an allotropic form of the atom, and think the facts of solution, &c., can all be explained by chemical combination between the salt and its solvent, as I have described, without this assumption. A good deal of weight has been laid on the explanation of the equality of heats of neutralisation of ionised bodies by supposing them to be dissociated. The explanation only pushes the difficulty one step further back. How does it happen that the heats of ionisation or dissociation during solution are many of them so nearly balanced by the allotropism of the ionic state? We are only explaining the obscure by the more obscure in thus reasoning. It is perfectly plain that double exchanging can never be continually taking place between molecules unless the heats of combination are the same, and consequently anything that explains one will explain the other. I

[1] Professor J. Emerson Reynolds informs me that such redistributions are recognised as occurring in complex molecules.

would rather look for an explanation of both in the direction I have already pointed towards as to the dependence of the forces between molecules upon their distance apart and on the way these and their internal energy are all bound together by the conditions of temperature equilibrium. The question is evidently in the highest degree complicated, and for a complete discussion must introduce the theory as to the nature of temperature equilibrium, and in the meanwhile it is misleading to pretend that a matter is simple which is in reality most obscure by speaking of acknowledged analogies as if they really explained anything.

It may be of interest to remark in connection with the question of the chinks within which molecules move that a very rough estimate can be made as to their size by considering the crude hypothesis that each ion is moved by the electric force near it acting on its ionic charge, and by calculating how long it would be in getting up its ionic velocity. Assuming that the ion moves like a body in a viscous liquid, the time it takes to get up its velocity must be a very small part of the time during which a current acts on it, and for which it obeys Ohm's law, because, for this to hold, the velocity must be independent of the time during which the current is acting. By some rough estimates as to the quantities involved it appears that the time during which an atom is acquiring its ionic velocity is somewhere about 10^{-15} of a second, and that the space it would acquire it in is about 10^{-20} of a centimetre. This seems as if the intermolecular bombardment distances were probably very small, and it shows that we can hardly expect Ohm's law to fail for electrolytes due to this cause until the rate of alternation of our current is comparable with that of light. Of course the actual jostling of an atom through the molecules can hardly be fairly represented by such a crude hypothesis as that it is like a body moving in a viscous fluid; yet such a calculation as the above may be of use in showing the sort of quantities we may have to deal with.

Professor Oliver Lodge said he had not been closely attending to these subjects during the past year or two, and accordingly only made a very few remarks, mainly with reference to the views he formerly expressed.

He had always endeavoured to moderate between the extreme dissociation views on the one hand, and those which require the molecule to be electrolytically torn asunder on the other. One reconciling fact is the chemically proved fact of double decomposition whenever two substances are mixed; this seemed to him to establish clearly that molecules are accustomed to interchange their atoms. Now, during the moment of interchange there is an instant of freedom, an instant of potential dissociation, and it is upon this that he had looked as the opportunity demanded by electric force to cause a slight diversion, sufficient in the long run to result in opposite atomic processions.

But, as Fitzgerald has somewhere pointed out, an infinitesimal moment of time is not sufficient to permit any finite effect, unless the forces acting are enormous, which in the middle of the liquid they certainly are not. This is therefore a difficulty, for if the atoms are solitary for any reasonable time, that amounts at once to actual dissociation, as postulated by Clausius. One may have to fall back, therefore, on the outlying atom stragglers from gross complex molecules as giving the necessary pseudo-freedom or potential dissociation which is all that Ohm's law and electrolytic facts demand, if one is to avoid admitting that extreme state of dissociation which physically seems to be so satisfactory and chemically so abhorrent.

But on this head it seems that no logical argument definitely asserting this latter view has been adduced. The fact that solutions do, in many respects, as shown by their osmotic pressure for instance, obey gaseous laws, is of high interest; but to argue from it that therefore their atoms must be in the same state of independent freedom as the atoms of a gas, is to commit the fallacy called by logicians 'the illicit process of the major.'

Moreover it is not quite apparent why (in Mr. Pickering's paper, for instance) the antithesis of the hydrate theory is supposed to be the dissociation theory. Free *molecules* in solution, rather than free *atoms*, would seem to be the opposite to the formation of definite chemical hydrates.

Lastly he hoped he might be permitted one word on the subject of an old communication by Professor Ostwald relating a hypothetical experiment on statically electrifying an electrolyte, which he controverted some year or two ago, and which has been referred to by Mr. Pickering as if it were equivalent to a perpetual-motion device. He wished to dissociate himself entirely from Mr. Pickering's position on this point, and to explain, what he had not yet had a good opportunity for explaining, that his published hostile remarks were made at first with the idea that the experiment was related as an experiment, and subsequently with the view that it is not very safe to use hypothetical experiments as controversial weapons. The view held by Professor Ostwald, that an electrolyte charged positively is so charged by reason of its hydrogen atoms looking outwards, while if charged negatively its oxygen atoms look outwards, is an extremely probable and instructive mode of regarding the matter. But an experiment establishing the truth of this view would have no necessary bearing on the dissociation controversy; in other words, the experiment suggested by Professor Ostwald, even if it could be performed, would not be a crucial one. The accepted laws of electrolysis already enable one to say what will happen when the minute current of a displaced electrostatic charge is passed through a liquid, with as much clearness as one can say what happens when a battery is applied to it. There is really no difference between the two cases, except the presence or absence of electrodes; for, as Professor Fitzgerald has said, the facing-out atoms exist in each case, only in one they face the electrodes, and in the other they face the air.

Professor OSTWALD read the following communication 'On the Electrical Behaviour of Semipermeable Membranes':—

If we fill two glass beakers with copper sulphate solution, put in them two copper wires connected with a couple of Leclanché cells and a galvanoscope, and close the circuit by a siphon filled with any electrolyte, which is prevented from mixing with the copper sulphate by covering the ends of the siphon with parchment paper, no phenomenon of special interest is to be noticed. We have an electrolytic circuit without polarisation, as used by Paalzow for the determination of the specific conductivities of liquids. By varying the liquid in the siphon only the total resistance of the circuit varies, and polarisation does not generally occur. If we fill the siphon with potassium ferrocyanide, nothing novel seems to go on at the first glance. But if we remember that on the contact of copper salts with ferrocyanides a *semipermeable membrane* of copper ferrocyanide is formed, through which, according to the observations of Traube, no copper salt can diffuse, we are led to a somewhat strange question. The fact that no copper salt can pass through the membrane is evidence that the copper ions existing in the salt solution are likewise unable to pass. But as the electricity in electrolytes travels only with the ponderable ions, we are met by the alternative either that the refusal of the copper (and ferrocyanide) ions to pass through the membrane will cause the current wholly to stop, or that the electricity will deposit the copper ions on the membrane and itself alone pass through. The semipermeable membrane must in the first case act as an *insulator*; in the second case it must act as a *metallic diaphragm*. Both these cases are so unexpected that the described experiment at once acquires a special interest.

By performing the experiment we find that the second alternative holds good. The current becomes rapidly weaker, and after ten minutes we can easily observe a very marked polarisation current in inverse direction to the primary current. After some hours of current the parchment paper containing the semipermeable membrane on the positive side is coated with a layer of metallic copper, and this is evidence *that the copper ions are filtered off by the semipermeable membrane.*

From this experiment it follows that the semipermeable membrane really acts as a sieve, not only as regards compounds, but also for ions, allowing some of them to pass and retaining others; for we know, for example, that potassium chloride can pass the membrane of copper prussiate, and therefore the ions K and Cl do so, while barium chloride and potassium ferrocyanide are retained. In the two last-mentioned cases one of the ions has the power of passing, but is retained by the other. At the first moment the Cl ions of the barium chloride will of course go through the membrane, while the barium ions stay behind. But by this separation a separation of positive and negative electricity also takes place, and thereby forces will arise tending to draw the Cl ions back. Finally a double layer of electricity is formed, causing a potential difference on both sides of the membrane, whose value depends only upon the molecular concentration of the electrolyte, and in no way upon its nature.

If the formation of the double layer is prevented, free diffusion of the passing ion takes place. By adding to the barium chloride some salt whose metal can pass through the membrane—for instance, some salt of potassium—the Cl ions at once will traverse the membrane, but the same number of K ions must go along with them. In this case, however, it may be assumed that the added potassium salt undergoes a double decomposition with the barium chloride, forming potassium chloride, which is able to diffuse through the membrane. But we can also cause the Cl ions to pass by putting some diffusible negative ions on the *outside* of the membrane—for instance, copper nitrate. Then we soon find chlorine outside and a nitrate inside the membrane. In this case it is impossible to assume a double decomposition, because both the salts are separated by the membrane, which prevents the diffusion of the barium chloride, as well as of the copper nitrate; and the explanation, by taking into account free migrating ions, seems to be the only sufficient one.

The above-mentioned double layers and potential differences, occurring at semipermeable membranes, when one of the ions of the electrolyte is retained, are probably the source of the potential differences and currents we meet with in living matter, because the cells of organisms are all coated with such semipermeable membranes. It is perhaps not too rash to hope that the ancient mystery of electrical fishes will find its solution on these lines.

Referring to the discussion Professor OSTWALD said :—Professor Fitzgerald has asked why the ions, when they are free, do not separate by diffusion. The answer is that they do. If we have a solution of HCl, for example, consisting to a great extent of H and Cl ions, in contact with pure water, the H ions, moving much faster than the Cl ions, take the lead in wandering into the water. But a separation of electricity hereby takes place, and every ion being charged with a great amount of either positive or negative electricity, the electrostatic forces resulting from the initial separation soon prevent further separation. Therefore water must take a positive potential against a solution of hydrogen chloride, and in general water must show against every electrolytic solution the potential of the faster ion.

These considerations, which lead to the whole theory of the potential differences between electrolytes, were first developed by W. Nernst ('Zeitsch. f. phys. Chem.' ii. 613, and iv. 129), who has confirmed them by various experiments; and further by M. Planck (Wied. 'Ann.' xl. 561). As far as I am aware, no theory of fluid-cells (*Flüssigkeitsketten*) had hitherto existed, and the possibility of developing one consistent with experiment from the principles first stated by Arrhenius is strong evidence in favour of his views.

Secondly, Professor Fitzgerald seeks for the source of energy required for the separation of, *e.g.*, Cl and H by dissolving HCl in water. This question is in accordance with the widely-spread assumption that a great expenditure of work must be done to effect this separation. As a great amount of heat is developed by forming HCl from its elements it seems evident that the same amount of energy must be restored to the elements in separating them. This is quite true if common hydrogen and chlorine were formed, but the ions H and Cl, existing in the aqueous solution of hydrogen chloride, are by no means identical with the so-called free elements. To use a word to which chemists are accustomed, the ions H and Cl are *allotropic forms* of these elements, similar to yellow and red phosphorus, and contain very different amounts of energy from those which they contain in their common state of hydrogen and chlorine gases. Therefore it is impossible to say anything *à priori* about the evolution or absorption of energy connected with the change from HCl gas to positively charged H ions and negatively charged Cl ions; we must interrogate facts; and these teach us that the ions generally contain much less energy than the elements in the common state, and therefore a great amount of energy is not called for in the transformation of, *e.g.*, HCl into the free ions H and Cl.

The elements in the state of ions being charged with great amounts of electricity, the very different tendency of the elements to assume the state of ions can be conveniently called their different affinity for electricity. This expression is of course only a *façon de parler*, but it gives a good description of the behaviour of the elements. The action, for example, of zinc on cupric sulphate solution, containing the ions Cu and SO_4, depends on the greater tendency of the zinc to form ions; therefore the zinc tears the positive electricity necessary for its existence as an ion from the copper ions, and deposits the latter as unelectrical, *i.e.* common metallic copper. The SO_4 ions, being no closer connected with the zinc than with the copper, act only as, owing to their negative charges, they render possible the existence of an equal number of positive ions, no matter of what nature.

If I am right Professor Fitzgerald is now ready to acknowledge the views of Arrhenius as *possible* ones, but he assumes that the facts explained by these views can also be explained by some other views, of which he has given some specimens. It is, of course, impossible to deny this. But as the theory of Arrhenius has done its work up to the present, and the new theory has yet its way to make, the former seems to have certain claims to be preferred. As the theory of Arrhenius has shown itself to be consistent with a very great number of facts, in the most various branches of physics and chemistry, the new theory must of necessity lead in all these cases to the same result as that of Arrhenius. Then the scientific world will have the wonderful spectacle of two theories, starting from different points of view, but leading everywhere to the same result. Science will then possess a twofold means of further investigation of some of its most difficult problems; a state of matters that cannot be too urgently wished for by all who have devoted their powers to such investigations.

In reply to Mr. Pickering's remark that the induction experiment upon electrolytic solutions described by me is opposed to the first principles of science, especially to the first law of thermodynamics, I wish only to remind him that by carrying out the common lecture experiment with two metallic balls and a charged body, we can get from the balls a spark, and therefore also an amount of energy. As no one hitherto has found in this experiment a contradiction to the law of the conservation of energy, I can leave the defence of my experiment to all teachers who annually perform this experiment in their lectures.

Professor Lodge has asked if the experiment in question has been carried out, and in what manner. The description of a series of such experiments has been given in the 'Zeitschr. f. phys. Chem.' iii. 1889, p. 120. The easiest way to demonstrate the liberation of ions in electrolytes by induction is to fill a glass jar covered on the outside with tinfoil with dilute sulphuric acid, to connect the outside with a source of positive electricity, and to insert in the sulphuric acid an earth-connected capillary electrode, *i.e.* a short Lippmann electrometer. The very minute bubbles of hydrogen developed by electrostatical actions can then easily be observed in the capillary tube on the boundary of the mercury and the sulphuric acid by help of a microscope.

Professor Armstrong has declared that the dissociation theory of electrolytes is unacceptable to chemists. As far as I am aware, there exists nowhere a real contradiction between chemical *facts* and the dissociation theory, but this theory only runs against all the time-honoured *feelings* of chemists. As feelings, although very powerful things, are at least variable with time and custom, it is to be expected that they will change sooner or later. The time is not very long past when the assumption that, in the vapour of ammonium chloride, hydrochloric acid and ammonia, which have 'so great an affinity for each other,' should exist separate from one another, ran in quite the same manner against the feelings of chemists. Now we are accustomed to this conception, and in the same manner chemists will speak in a year or two as quietly of the free ions as they now speak of the uncombined mixture of hydrochloric acid and ammonia in the gaseous state.

But it should not be forgotten that a great many purely chemical facts—in the first place the great generality and regularity of the chemical reactions of electrolytes as used in analytical chemistry, in opposition to the variability and irregularity of the behaviour of non-electrolytes, especially of organic bodies—have found their first explanation in the theory of electrolytic dissociation. The objection against this theory, that if the ions of salts exist in a free state this would not be any ground for the law of constant proportion between acid ions and metals, is easily refuted. For, according to Faraday's law, all chemically equivalent amounts of positive and negative ions are charged with equal amounts of electricity; in an electrically neutral solution, as all ordinary solutions are, there cannot but exist an exact equivalent number of positive and negative ions. We see, therefore, the law of Faraday connected in the closest manner with Richter's law of chemical equivalents; if the one holds good, the other must also hold good, and *vice versâ*.

Professor Armstrong has asked why water does not split into ions, while hydrogen chloride, a body similar to water, does. But has Professor Armstrong forgotten that liquid hydrogen chloride, like pure water, is an *insulator* for the electric current, as was found long ago by Gore, an observation afterwards confirmed by Bleekrode? It has been stated by F. Kohlrausch that at ordinary temperatures no pure liquid is a good electrolyte. The theory of Arrhenius is still in this point the only one which explains this strange fact; pure liquids do not conduct, because their molecules have no space to resolve themselves into ions.

It is therefore not improbable that water would conduct electrolytically if we could find a suitable solvent for it. An investigation in this direction would be of very great interest, but not without grave difficulties.

To a certain, but very small extent, water too contains ions, namely, H and OH. This is shown by the hydrolytic action of water on the salts of weak acids and bases, the amount of H or OH ions dissociated from these acids or bases being in such cases comparable with the amount of the same ions in water. Then the latter acts as a very weak acid or base, and the action follows the common law of masses, as J. Walker has shown ('Zeitsch. f. phys. Chem.' iv. 319).

Professor van 't Hoff stated his conviction that we were forced on theoretical grounds, thermodynamic as well as kinetic, to admit in dilute solutions a law corresponding to that of Avogadro, differing from this only in its bearing upon 'osmotic' instead of 'ordinary' pressure. He insisted on the necessity of dissociation in the case of KCl as a consequence which, on this line of argument, it was impossible to escape from. On the other hand, an ordinary separation into free atoms was in evident contradiction to all we knew about them, as in the vapour of iodine and mercury. These objections become invalid when we admit a splitting up into ions, which by their enormous electrical charge ought to be widely different from what we might expect in ordinary atoms, and hence it is that Arrhenius's 'electrolytic dissociation hypothesis' was at once most favourably received by the adherents of the 'osmotic pressure theory.' Since then both have become closely allied by the fact that the dissociated fraction, according to the last, agreed with that admitted by the first on wholly different grounds.

In reply to the objections raised by Professor Fitzgerald, it may be observed, with respect to the theoretical foundation of the osmotic pressure law, that the action on a semipermeable diaphragm is due, partly to the shock of the dissolved molecules, partly to the difference of forces acting upon them, from the solvent on one side, and from the solution on the other. Now, the result of the shock is directly proportional to the concentration, whereas that of the attraction is proportional to the square: thus in very dilute solutions the second action vanishes when compared with the first, and the shock is alone the origin of pressure as it is in gases. However, he insisted on these views as more intended to popularise than to prove the laws in question. If we want to do the last on kinetic grounds, we must take everything into account—movement of the molecules of the two substances mixed, action on themselves and on each other. Now, this has been just recently done by van der Waals, and the result is a very complicated formula, simplified, however, for dilute solutions into this statement, 'that the dissolved molecules act on a semipermeable membrane with strictly the same force as they would do on an ordinary membrane in the gaseous state.' So from a kinetic point of view the law of Avogadro and the 'osmotic pressure' law stand on the same basis.

Mr. Pickering commits a fundamental error in supposing that the osmotic pressure theory arrives at 0·63 as the number with which we had to multiply the solvent's molecular weight in order to get the so-called 'constant of depression.' Such conclusion was never drawn from the theory in question; it was the formula $\frac{0{\cdot}02T^2}{W}$ that was deduced. The value 0·63 was an empirical one, introduced by Raoult. This difference has urged Professor Eykman to a very extensive experimental research, the conclusion of which was so evident that in the July number of the 'Annales de Chimie et de Physique' Raoult openly accepts the value $\frac{0{\cdot}02T^2}{W}$. On p. 359 Raoult states: 'L'abaissement a du point de congélation produit par une molécule dissoute dans 100 molécules dissolvantes est, d'après M. van 't Hoff, donné par l'expression $a = 0{\cdot}02\,\frac{T^2}{L}i$, dans laquelle T est la température absolue de congélation et L sa chaleur latente moléculaire de fusion.' In addition, on p. 361, he says: 'L'accord entre l'expérience et la théorie est donc, sur tous les points, aussi complet qu'on peut le désirer en pareille matière.' No one now defends the value 0·63, and a good deal of the objection which Mr. Pickering directs against it has no bearing on the osmotic pressure theory itself.

Mr. W. N. Shaw remarked that the meaning of the term solvent used by physicists when referring to water, alcohol, and the like, is somewhat widely extended when it is understood to include $100(H_2SO_4.H_2O)$, and the other equally complex solvents of Table I. of Mr. Pickering's paper.

An ordinary solvent could not fairly be regarded as being 'inert' and 'having no action whatever' when it was claimed that the solvent caused the dissociation of a large portion of the dissolved salt. The action is in fact most remarkable, and is the important point now requiring investigation and explanation. This action has been clearly illustrated by Mr. W. Coldridge ('Phil. Mag.' May 1890, p. 383), who has endeavoured at Cambridge to ascertain the circumstances under which stannic chloride can be brought into the dissociated or electrolytic condition. The compound is interesting, since water and alcohol produce well-known and remarkable actions upon it; moreover it is comparatively easily prepared in the pure state. It appears from the paper referred to that stannic chloride can be mixed with chloroform without receiving any conducting power. It will also absorb a considerable quantity of dry H_2S gas without chemical action, and again without becoming electrolytic; whereas the addition of a drop of water or alcohol to the non-electrolytic mixture immediately gives rise to chemical action with a deposit of tin sulphide, the liquid becoming at the same time electrolytic.

The action of water or alcohol seems to be clearly different in this case in some fundamental manner from that of H_2S or chloroform.

Mr. Shaw also drew attention to the diagram (fig. 1) in Mr. Pickering's paper, from which, if he understood it correctly, it appears that for very weak solutions the 'molecular depressions' produced by certain salts are the same for solutions containing ·08 molecule per $100H_2O$ as they are for infinitely dilute solutions.

Mr. Pickering remarked that there were very strong positive arguments in favour of the hydrate theory, and that his opponents had in no way controverted them. Even if they succeeded in refuting all the objections which he had raised against the physical theory, this theory could not be established till it was shown that other theories were either untenable or less satisfactory.

The freezing-points of sulphuric acid solution calculated by Arrhenius certainly showed a very striking agreement with the observed values; but, before attributing much weight to this agreement, it would be necessary to examine carefully the details of the calculations, for there are considerable sources of doubt and difficulty in applying the values for the conductivity of weak sulphuric acid solutions; but even if no exceptions could be taken to the calculations, it must be remembered that the agreement exhibited extended only up to 1 per cent. solutions, or 0°·4 depression, whereas, according to the values quoted above, his theory offered an equally good agreement up to 30 per cent., or 34° depression, and, according to values given elsewhere, a similar agreement extended, with certain exceptions, up to 94 per cent. It must also be remembered that according to the chemical as well as the physical theory there must be a mathematical connection between the freezing-points, conductivities, and all other properties of solutions. The freezing-point curve shows irregularities, and so also does the conductivity curve; the chemical theory explains these irregularities, whereas according to the physical theory they should not exist.

Professor van 't Hoff pointed out that according to his theory the freezing-points were influenced by the nature of the solvent; but this does not remove the objection that the nature and amount of the *dissolved substance* (even when this is a non-electrolyte) are found to influence the results. Professor van 't Hoff had misunderstood what had been said about Raoult's constant: he (Mr. Pickering) was well aware that this constant and that deduced in the osmotic pressure theory were quite different.

Professor Ostwald stated that his experiment of bringing a charged body up to a solution, dividing the latter, and removing the charged body, was precisely analogous to a similar operation performed on a metallic conductor instead of a solution. This is undoubtedly the case, but in both instances there is an expenditure of mechanical energy, for more work must be done to remove the charged body from the separated and now charged solution or conductor than was required to bring it up to it; energy has been expended, and as a result we get a current and a certain amount of chemical decomposition: how can this prove that the substance was decomposed to start with? All that it could prove seemed to be that a current developed by electrostatic induction produced the same results both qualitatively and quantitatively as an ordinary galvanic current—a fact which has been established long ago.

Considerable stress has been laid on the constancy of the heat of neutralisation as an argument in favour of the physical theory, but it must be remembered that this constancy has received an equally simple explanation on the hydrate theory.

At the conclusion of the discussion Dr. Gladstone remarked upon the satisfactory circumstance that by means of the meeting of the British Association scientific men had been brought together from the Continent and various parts of England who held diametrically opposite opinions upon the subjects discussed, but that there had ensued a *rapprochement* and mutual understanding which could not fail to render the views of both sides more accurate representations of fact.

Provisional Report of a Committee, consisting of Professors H. M'Leod, F.R.S., W. Ramsay, F.R.S., *and* Messrs. J. T. Cundall *and* W. A. Shenstone (*Secretary*), *appointed to investigate the Influence of the Silent Discharge of Electricity on Oxygen and other Gases.*

It was found, as previously reported, about two years ago, that the work of the Committee necessitated the production of silent discharge of electricity of a more constant character than that which has hitherto been sufficient for experiments on the electrification of gases. The attaining of this object was at first very seriously delayed by circumstances beyond the control of the Committee. The work was, however, resumed during the latter part of the year 1888–9, and has been continued since the Newcastle Meeting. Satisfactory progress has been made, and apparatus has now been constructed which promises to give satisfactory results. It will therefore be possible now to continue the work of the Committee from the stage to which it was carried by Messrs. Shenstone and Cundall in the experiments which have already been reported to the Association.

The sum of 5*l.* granted for the use of the Committee at the last meeting has been expended, chiefly in the construction of electrical apparatus.

As the expenditure of the Committee is likely to be small during the coming year, it is requested that the Committee be reappointed without a grant.

Report of the Committee, consisting of General FESTING (*Chairman*), Dr. H. E. ARMSTRONG (*Secretary*), Captain ABNEY, *and* Professor W. N. HARTLEY, *on the Absorption Spectra of Pure Compounds.*

THE spectra of a number of substances have been determined during the year, but as the object of the Committee is to draw definite conclusions as to the relation between structure and properties throughout series of related compounds, and the material at disposal is not yet sufficient for this purpose, they desire that they may be reappointed in order that the investigation may be continued.

Report of the Committee, consisting of Dr. H. WOODWARD, Mr. R. ETHERIDGE, Mr. R. KIDSTON, *the* Rev. G. F. WHIDBORNE, *and* Mr. J. E. MARR (*Secretary*), *appointed for considering the best methods for the Registration of all Type Specimens of Fossils in the British Isles, and reporting on the same.*

THE Committee have considered the best methods of obtaining records of the type specimens of British Fossils, and they would recommend that a circular letter and record-sheet similar to the annexed forms be sent to curators of museums and owners of private collections:—

Sir,—A Committee having been appointed by the General Committee of the Association for 'considering the best methods for the registration of all type specimens of fossils in the British Isles,' the Secretary of the Committee would be greatly obliged if you would kindly fill in the accompanying form with particulars concerning any type specimens of British Fossils which are preserved in the collection under your charge.[1] The forms should be returned as soon as possible to , who will be glad to give further information, if required.

(*Form of Record Sheet.*)

Name under which first described	Where originally described and figured	Name under which now generally recorded	Locality or localities	Exact stratigraphical horizon	In what collection deposited	Nature (whether entire, or if not, what portion preserved, &c.)

The Committee would suggest that they be reappointed.

[1] Should these returns be printed by the British Association, you would be supplied with copies for the use of your museum.

Eighteenth Report of the Committee, consisting of Professor PRESTWICH, Dr. H. W. CROSSKEY, Professors W. BOYD DAWKINS, T. MCKENNY HUGHES, *and* T. G. BONNEY, *and* Messrs. C. E. DE RANCE, W. PENGELLY, J. PLANT, *and* R. H. TIDDEMAN, *appointed for the purpose of recording the Position, Height above the Sea, Lithological Characters, Size, and Origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation.* (*Drawn up by* Dr. CROSSKEY, *Secretary.*)

DURING the past year an important step has been taken towards the completion of the researches of the Committee in one district and the giving a scientific arrangement to the vast number of facts that have been collected.

Mr. Frederick W. Martin, F.G.S. (of Birmingham), who has made several valuable contributions to the reports of the Committee, has completed the main portion of his personal survey of the boulders of the Midland district, and has collected together in their proper order the whole of the facts he has ascertained, and described with precision and accuracy the general results of his observations. Mr. Martin has, moreover, finished a map showing the distribution of the Midland boulders, which both corrects many errors into which previous observers have fallen and places the whole series of facts before the eye in a systematic form. The Birmingham Philosophical Society has materially aided the work of this Committee by including in its 'Proceedings' for the current year Mr. Martin's notes and map. Were the same scientific method of treatment applied to the study of the erratics of each district in England and Wales results of equal value would, without doubt, be obtained.

The Committee would strongly urge upon all local scientific societies to undertake this work. Not only is it of the largest value to all students on glacial geology, but the destruction of erratics is going on so rapidly that each year's delay reduces the number of ascertainable facts.

Without entering into the theoretical questions which are beyond its province, the Committee thinks it well to point out a few of the general results of the survey of the Midlands, in order that other observers may examine how far they differ from or agree with the phenomena presented in their respective districts.

So far as the Midlands are concerned, the facts with respect to the erratics appear to establish the following points:—

1. The boulders have been deposited at distinct periods. At least two of these periods can be well ascertained. In some cases the collection of erratics which have been supposed to show the 'intercrossing' of their streams are really the remains of distinct periods of action; not that there has been *no* intercrossing, but that all the supposed cases of it are not accurately described by that term.

2. There are deposits of boulders in the Midland area which are entirely distinct from each other, boulders from special districts being grouped together.

3. There are deposits of boulders in which those from different and

distant sources are to some extent intermixed; and this intermixture of streams or boulders has to be studied in connection with the physical geography of the country during the Glacial epoch.

4. Local hills have formed no effective barrier to some part of the distribution of boulders. In the Midlands, *e.g.*, they are abundant at a level of 618 feet, and not unfrequently lie on the edges of the precipitous side of a hill.

5. Some streams of boulder, however, have travelled under conditions imposed by the hills and valleys as they now exist.

6. There are glaciated boulders of local origin intermixed with those not of local origin; but it would seem that where the northern erratics are numerous very few of these are intermixed.

7. There is also a distinct distribution of boulders from local hills (as, *e.g.*, from Rowley Regis).

8. There are boulders at almost every level, and, it may be added, beds of boulders are sometimes separated from each other in section by clays and sands, occasional boulders occurring in the separating clays.

9. A very considerable proportion of the largest boulders are upon the surface, or just beneath the surface; how far clays and sands may have been washed away from them, however, is a question.

10. There are notable differences in the shapes of the boulders. Many are angular and subangular; many have their edges much rounded off; others are rough and broken as though just torn from the parent rock. In some collections of boulders there are signs of considerable rolling and wearing as by water; in others signs of ice action are fresh and unworn.

Warwickshire.

Mr. W. Jerome Harrison, F.G.S., forwards a note on three boulders in South Warwickshire. In North Warwickshire the watershed which divides the rivers running to the E. and W. coasts of England respectively forms the boundary line on the coast to the remarkable collection of Welsh and Lake District and Scotch rocks described in previous reports as occurring in the Midlands. Of boulder clays equivalent to those found in the district around Birmingham, Mr. Harrison has found no trace in S. Warwickshire. The surface deposits there are mainly a light quartzose gravel, the stones small, with occasional flints. Erratics of any size are rare.

The two Sherbourn Boulders.—Two and a half miles S. of the town of Warwick lies the village of Sherbourn, close to the right bank of the Avon. At the point where the village street joins the high road is a block of Millstone Grit. It measures 2 ft. 5 in. × 1 ft. 10 in. × 1 ft. The second Sherbourn boulder lies further up the village street, nearly opposite the school-house. This is a granite block, the felspar of a reddish colour. Its dimensions are 3 ft. 2 in. × 2 ft. 6 in. × 1 ft. 9 in.

The Exhall Boulder.—The village of Exhall is 9 miles S.W. of Sherbourn, and 5 miles due W. of Stratford-on-Avon. The boulder lies by the roadside at the east end of the village. It is a quartzose block, with green specks, possibly vein-quartz. It rests on the trias near the junction with the Rhætic beds. The surface beds of this district appear to be thin gravel, composed of small quartzose pebbles (in which are found Orthis Budleighensis and worm-tracks), but with many angular pieces of chert flint.

Lancashire and Cheshire.

Mr. Bernard Hobson, B.Sc., F.G.S. (Assistant Lecturer in Geology, Owens College), forwards an account of two boulders dug up in making a new sewer in Granville Road, Fallowfield, near Manchester. The nearest bench-mark is 115·7 ft., and as the ground is very flat in the neighbourhood, that will be about the height of Granville Road. Both boulders were about 14 ft. below the surface, and in the boulder clay.

Boulder A, well rounded; no striæ; size, 2 ft. 2 in. × 1 ft. 6 in. × 1 ft. 5 in. It is a Buttermere syenite. Specific gravity 2·61.

Boulder B, subangular; flattish; size, 2 ft. 10 in. × 1 ft. 9 in. × 1 ft. 1 in. It is striated transversely in the direction of the 1 ft. 9 in. measurement. It is an andesite, and agrees pretty closely with the very large boulder found in 1888 opposite No. 266 Oxford Road, Manchester, and which is mounted on a pedestal in the Owens College quadrangle. Specific gravity 2·8.

Specimens of both boulders have been deposited in Owens College Museum. The Committee would strongly urge that this example should be generally followed, and that a specimen of any boulder found in any locality should be placed in the nearest museum, with a careful note of the exact spot from which it was taken.

The subjoined notes of erratics have been received from Mr. Percy F. Kendall, F.G.S.:—

Erratic blocks.—(1) On the cutting of the Manchester Ship Canal about a quarter of a mile west of the Trafford Road Bridge, Old Trafford, Manchester. Size $6 \times 4\frac{1}{2} \times 3$ (+) feet; in shape subangular. The eastern end is well rounded, and the western angular (not subangular). Its longest axis is almost precisely E. and W. (true, not magnetic); the north side is well scratched in the direction of long axis. It is a Coal Measure sandstone containing fragmentary plant-remains. The sandstone is bluish-grey within, but weathers externally, and to a depth of about $\frac{1}{2}$ to 2 inches, to a tea-green colour and is then very soft.

This boulder rests upon boulder clay, and is surrounded by old silts and gravels of the river Irwell. The Irwell is distant about 150 yards. Two smaller stones weighing about one hundredweight each lay alongside the one here described. They are of identical composition, and it is an important fact that about six months ago (June or July 1889) several large boulders of the same sandstone were met with *in* the boulder clay at a distance of 50 to 100 yards away. In the river-gravels at the same place many stones, large and small, of the same sandstone are to be observed. In the course of a careful examination of the whole line of the canal, I have not observed this sandstone elsewhere.

(2) Just north of Windgather Rocks, Taxal, Cheshire. Approximate weight, 2 tons; rounded; has been moved; not scratched, or scratches not preserved. It is an Eskdale granite (sheared or cleaved variety). It is 1,150 feet (by aneroid) above the sea. The Photographic Section of the Stockport Society of Naturalists has a good photograph. It is not connected with any long ridges of gravel or sand. It rests upon the Millstone Grit.

(3) A little to the north of the Windgather Rocks, Taxal, built into a wall beside a stile about 200 yards from farmhouse. Approximate weight, 2 tons; rounded; has been moved; no striæ visible. It is a

Buttermere granophyre. It is 1,150 feet above the sea; isolated; is exposed on the surface; and rests on the Millstone Grit.

(4) A little to north of Windgather Rocks, Taxal. The stone was on the road leading from the farmhouse. The observations were made just *after* the stone had been broken up. Approximate weight, 2 tons; rounded (?); had been moved. It is one of the well-known Borrodale andesitic lavas, such as abound in the boulder clay in Lancashire and Cheshire. It is 1,150 feet above the sea, and rests on the Millstone Grit.

The three boulders described as occurring at the Windgather Rocks are all exposed on the surface. There are no beds of gravel, sand or clay visible in the neighbourhood, but a good many foreign stones of small dimensions are lying about. Amongst them I saw the granite of Loch Doon.

Mr. Kendall reports a striking observation he has made with respect to the distribution of boulders derived from local rocks in Lancashire and Cheshire. He has made a careful examination of these boulders as likely to afford valuable indications of the agency by which their transport was effected. There are (he states) in this district two rocks which are very easily identified, and whose outcrops are well known, viz. the Ardwick limestone and the fossiliferous Permian limestones. Mr. Kendall has searched carefully for these two rocks, and briefly states the result as follows: *boulders in this district never occur either to the N. or W. of the parent rock.*

A very striking example of this occurs, Mr. Kendall writes, in the railway cutting between Wilmslow Road, Fallowfield, and Slade Lane, Burnage. At the base of the glacial beds exposed, fragments of the Permian marl and sandstones were abundant; and of the Ardwick limestone massive blocks had been torn off and embedded in the boulder clay *at all angles*, and some of them have received ice scratches, but the movement which dislodged them was, broadly speaking, from W. to E., and in no single instance could a fragment be found to the westward of its natural outcrop. Mr. Kendall adds that this is no isolated observation at a single exposure, but that it is, he believes, the law of boulder transport for S. Lancashire and Cheshire.

Should more extended observations confirm this very remarkable generalisation, light will be thrown upon some of the most difficult problems in glacial geology.

Mr. Kendall draws attention to another very important point connected with the distribution of erratics. After very diligent search he has not been able to find a single Manx or Irish rock in Lancashire. The flints are usually referred to the Irish chalk; but he contends that their proximate derivation may have been from some other source—as, for example, from some bed of gravel which may have been deposited in the Irish Sea in pre-Glacial times.

Without pronouncing any opinion on the theoretical questions involved, the Committee would strongly urge upon all who are engaged in these researches the importance of carefully recording the facts connected with the *distribution* of boulders, whether derived from bed rocks or from distant mountains, and also of paying attention to the boulders *which are absent* as well as to those *which are present in* any district.

Observations similar to those made by Mr. Kendall, if extended over England, will yield results of the greatest possible value.

Boulders from Rawtenstall.—By the kindness of Mr. Charles Bucknill, Mr. J. W. Gray and Mr. P. F. Kendall are enabled to record the following boulders from the immediate neighbourhood of Rawtenstall. The determinations were made from specimens submitted by Mr. Bucknill.

Borrowdale ash, 2; Borrowdale lava, 7; Borrowdale amygdaloidal andesite, 2; volcanic rocks, source undetermined, 2; Buttermere 'syenite' (granophyre), 2; granites, source undetermined, 5; Criffel granite, 1; Loch Doon granite, 2; Eskdale granite, 10; Rig o' Burnfoot granite, 1; granite with much muscovite, source undetermined, 1; vein quartz (like that from the Borrowdale series), 5; vein quartz with ochreous sandstone, 1; mountain limestone chert, 1; mountain limestone, 3; red sandstone, 2; hæmatite (fresh), 1; total 48.

Mr. J. Horsfall (a member of the Rochdale Literary and Scientific Society) describes a boulder in Wardle Parish, Buckley Pasture, Rochdale, just behind the college at Clough Bottom, a little to the N.W. Size, 10 ft. × 5 ft. × 4 ft. 6 in.; angular; longest axis E. to W. It is composed of a sandstone different from the adjoining rock, but a similar rock occurs on Rushy Hill about half a mile W. It is about 600 ft. above the sea; is isolated, and rests on shale.

A group of erratics is reported by the same observer as occurring in Spotland Parish, Nick-o'-the-Bank Farm, about 200 yards below the culvert in the brook at the lower end of Ferndale Wood. It has been exposed by the stream, which has cut a passage through it. The largest boulder is 3 ft. × 2 ft. × 1 ft. 6 in.; others vary in size from this down to a foot in diameter, and there are hundreds of smaller dimensions. They are much rounded, except the largest, which is subangular. There are distinct striations on one of the boulders, which is partly imbedded in the soil by the side of the brook. The striations, seven or eight in number, run along the whole length of the boulder (which is 2 ft. long), and are in the direction of its longest axis.

This group consists of andesites, &c., from the Lake district, with a few specimens of Criffel granite; with angular and rounded sandstones and shales intermixed. It extends over an area of 80 or 100 yards, and is about 800 ft. above the sea-level.

The following group occurs in Cheshire at the localities indicated.

A. Greave Fold, Werneth Low, near Romiley. B. Summit of Werneth Low, Cheshire. The figures denote the number of boulders found.

Eskdale granite, A 1, B 1; Buttermere 'syenite,' A 1; Borrowdale andesite, A 1, B 6; Borrowdale agglomerate, A 3; Borrowdale rhyolite, B 1; Borrowdale porphyrite, A 1; Silurian grit, A 4, B 1; Coal Measure sandstone, A 2; quartzite, B 1; quartzite pebble from Bunter, B 1.

Close to the highest point on Werneth Low, 821 ft. above Ordnance datum, is a deposit of boulder clay with scratched stones.

Derbyshire.

The Committee are obliged to Mr. J. W. Gray, F.G.S., and Mr. P. F. Kendall, F.G.S., for the following important 'Notes on some Erratics at High Levels in Derbyshire.'

The writers desire to place on record some observations they have made in the course of an examination of the hill country on the western side of the Pennine axis, with a view to the demarcation of the limits of the drift containing erratics of the types prevalent in South Lancashire and Cheshire.

The country to which the following remarks must be taken to apply is that great ridge which culminates in the sharp escarpment called the Windgather Rocks. The ridge runs nearly N. and S., and the valley on the western side (the Kettleshulme Valley) is broad and comparatively unobstructed to the N., where it opens out towards the lower ground about Disley; but the eastern valley becomes much involved to the northward amongst a succession of hills, such as Chinley Churn and Eccles Pike. The ridge before referred to is excavated by a very deep longitudinal T-shaped valley which dies out north and south, but has a deep gorge-like outlet on the E. opening into the Goyt Valley on that side.

Commencing our search at Taxal on the east, we found small erratics at about 600 ft., and traced them intermittently upward in a southerly direction to the farmhouse called 'Overton,' where there was a block of Buttermere 'syenite' weighing about 2 cwt. built into one of the barns; thence we traced them in increasing numbers right up to the summit of the spur which separates the subsidiary longitudinal valley from the main valley. Over the spur we lost the trace, and in our descent and re-ascent up to the Windgather Rocks the clue was not taken up. At the Windgather Rocks themselves we looked carefully for traces of ice-scratches, but nothing of the kind was to be seen. It may be well to remark that the extreme edge of the hill consists of bare millstone grit dipping E. at a high angle, and making a precipitous escarpment upon the west about 20 to 30 ft. in height. A portion of the length of this is a natural face, but some quarrying has been done. The first trace of erratics is met with in the position described on the forms recording the boulders, viz.: about 200 yards from the farmhouse on the ridge N. of the Windgather Rocks. This point is north of the head of the valley which cleaves the hill.

Amongst the erratics noted blue and green andesitic rocks of the Borrowdale type greatly predominate, but the majority of the larger stones are of Buttermere 'syenite.' Besides there is Eskdale granite, a south Scottish granite, purple quartzite such as is found in the Bunter, and, finally, a white quartzite of saccharoid texture much resembling that of the Wrekin, but lacking the rhyolitic particles which are so common in that rock.[1] We would draw attention to the fact that in the ascent of the hill from the E. the erratics increase in number with the altitude.

YORKSHIRE.

Valuable contributions have been received for several years past from the Committee formed in Yorkshire for the express purpose of exploring and recording the remarkable and numerous erratic boulders of that county.

Mr. S. Chadwick, F.G.S., Malton, has been now appointed secretary, and has forwarded the following reports.

[1] This quartzite is the first erratic to be observed in descending the Kettleshulme Valley from Jenkin Chapel.

The Committee cannot but express its deep regret at the death of the former secretary of the Yorkshire Committee, Mr. S. A. Adamson, and record its recognition of the great value of his services.

Southburn, Parish of Kirkburn.—In the township of Southburn, parish Kirkburn, on the estate owned and occupied by Mr. J. Walker, about a mile S.E. of Southburn Church, are a large number of boulders, some of which measure

1 ft. 11 in. ×	1 ft. 4 in.	and	9 in.	above ground.
1 ft. 5 in. ×	9 in.	„	7 in.	„ „
1 ft. 3 in. ×	10 in.	„	9 in.	„ „
1 ft. 3 in. ×	9 in.	„	8 in.	„ „
11 in. ×	10 in.	„	8 in.	„ „
11 in. ×	9 in.	„	8 in.	„ „
11 in. ×	8 in.	„	6 in.	„ „
10 in. ×	9 in.	„	10 in.	„ „

They have all been moved to their present position. There are no striations visible. There were specimens of whinstone, mountain limestone, red granite, &c., &c., in the yard, among heaps of stones; most of them are from the North. The greater proportion are whinstone; they are about 100 ft. above sea-level. The boulders have been collected from the adjoining land and used for paving the yards.

Southburn.—1. In the township of Southburn, parish of Kirkburn, on the estate of A. Brown, Esq., about a mile S.E. of Southburn Church. In a stackyard occupied by A. Foster, Esq., is a boulder. It is 32 in. × 22 × 19 lying close to the roadside. It is subangular. There is a distinct stria on one side of the stone more across than lengthways. 'Colour nearly black, with rough granules like diorite or coarse whinstone. It was found imbedded in the foundation of some old thatched cottages, and is about 100 ft. above sea-level.' There is no photograph of it. It rests upon chalky gravel.

2. In the township of Southburn, parish of Kirkburn, on the estate owned by A. Brown, Esq., farm occupied by A. Foster, Esq. At the north end of the farmhouse is a boulder 2 ft. 8 in. long, 1 ft. 5 in. broad, and 1 ft. 3 in. out of the ground. Its shape is rounded but oblong, and it has been so placed to protect other property adjoining it. On the inner side are fine grooves or markings, varying from 9 in. long, $\frac{1}{4}$ in. broad, $\frac{1}{8}$ in. in depth, all running in the direction of the longer axis. It is composed of whinstone; the nearest rock of this kind would be Goathland, 30 miles away. It was found in the foundation of an old house pulled down about twenty years ago, and is 100 ft. above sea-level. It is not a boundary stone; there is no photograph of it; the boulder is at the end of Mr. Foster's farm, and rests upon a bed of gravel.

Lowthorpe.—1. In the parish of Lowthorpe, estate of W. H. St. Quintin, Esq., $\frac{1}{4}$ mile N.W. of Lowthorpe Station, N.E.R., and 40 yards east of Lowthorpe Road. 2 ft. 2 in. × 1 ft. 8 in. × 1ft. 3 in., subangular, has been moved to present position; no ice markings; composed of whinstone; about 50 ft. above sea-level; nearest locality for whinstone is about 40 miles N.W.; resting upon boulder clay. An old lady living in a cottage close by remembers the stone to have been in its present position over sixty years.

2. In the parish of Lowthorpe, estate of W. H. St. Quintin, Esq., on the Lowthorpe roadside leading to railway station about $\frac{1}{2}$ mile N.W. Within a radius of 40 yards are a group of boulders, measuring—

1 ft. 6 in. ×	1 ft. 6 in. ×		11 in.;	Red sandstone.
1 ft. 6 in. ×	1 ft. 5 in. ×	1 ft.	3 in.;	Mountain limestone.
2 ft. ×	1 ft. 5 in. ×	1 ft.	4 in.;	Estuarine sandstone.
1 ft. ×	1 ft. ×		9 in.;	Whinstone.
1 ft. 2 in. ×	1 ft. ×		10 in.;	Whinstone.

Several of these have been taken out of the adjoining fields during the last ten years, and are now resting on boulder clay at about 60 ft. above sea-level. In no case do they show any traces of ice scratches, &c.

Scarborough.—In the parish of Newby, on the north side of Scarborough estate, belonging to the Burial Board, and now used as a cemetery, about $\frac{1}{2}$ mile west of the coast and 100 yards east of the Scarborough Whitby Railway. It is 4 ft. 10 in. × 3 ft. 2 in. × 2 ft. 9 in., subangular, has been moved; there are no ice marks; composed of hard, compact sandstone resting on boulder drift about 50 ft. above sea-level.

Scalby (North Riding).—In the parish of Scalby (near Scarborough), estate, Dr. Rook's, about $1\frac{1}{2}$ mile west of the coast and $\frac{1}{2}$ mile east of the village of Stainton Dale, at the bottom of Stainton Dale beck, 1 ft. 8 in. × 1 ft. 2 in. × 1 ft., dolerite; another one is 1 ft. 11 in. × 1 ft. 4 in. × 9 in., whinstone. Both are subangular; nearest locality about 10 miles; N.W. of Whin Dyke, Robinhood's Bay; resting on boulder drift about 100 ft. above sea-level.

Underneath the boulder drift is composed of estuarine conglomerite.

Ruston Parva (East Riding).—In the parish of Ruston Parva, about $2\frac{1}{2}$ miles west of Lowthorpe Station, N.E. Railway, East Riding of Yorkshire, there is a large block of diorite forming a protection for the angle of the road leading from Driffield to Kilham at the west side of the village of Ruston Parva. The land is in the occupation of Mr. Jefferson, but owned by W. H. St. Quintin, Esq., of Scampston Hall, near Malton. It is apparently a very large boulder, as it stands in an upright position 28 in. out of the ground, whilst its greatest length across the exposed surface is 28 in. by 25 in. thick.

It is quite angular, almost indicating from its surface that an attempt has been made to reduce its size.

So far as can be ascertained, the boulder has been in its present position for upwards of 100 years; for, although it must have been placed in its present position, no one's memory carries so far back.

There are no ruts, grooving, or striation to be seen upon its surface; it shows no indication of having been ground in any way.

The stone is dark diorite, and there is no rock of this nature within 50 miles. Its position is about 100 ft. above the level of the sea, resting on boulder clay.

Speeton.—In the parish of Speeton, near Filey, on the farm occupied by Mr. J. Jordan's trustees; estate of Lord Londesborough. The locality is commonly known as Speeton Gap. At the bottom of the gap, just where the footpath crosses the beck, and about 250 yards N.W. of the beach, are five large boulders.

No. 1 is 3 ft. 10 in. × 2 ft. 3 in. × 1 ft. 8 in. above ground. Rounded to subangular; has not been moved; longest axis E. and W.; shows groovings in direction of longest axis, some being from 11 to 9 in. long, $\frac{1}{4}$ in. deep, and $\frac{1}{2}$ to $\frac{1}{4}$ in. wide; close-grained sandstone.

No. 2.—3 ft. × 1 ft. 9 in. × 1 ft. 7 in. Rounded; has not been moved; longest axis, N.E. and S.W.; dolerite.

No. 3.—2 ft. 9 in. × 2 ft. × 1 ft. 8 in. Rounded to subangular; has not been moved; longest axis N.E. and S.W.; shows groovings and striæ in direction of longest axis, some being nearly a foot long; Shap Fell granite.

No. 4.—2 ft. 1 in. × 1 ft. 10 in. × 1 ft. 8 in. Rounded; whinstone.

No. 5.—3 ft. 8 in. × 2 ft 6 in. × 1 ft. 3 in. Flat angular block of fine grained sandstone.

These are all about 50 ft. above sea-level, and rest upon the Red Chalk or lower beds of the Lower Chalk.

NOTE.—All these boulders are scattered over a distance of about 50 yards up the creek in a westerly direction.

In Speeton Gap, and following the course of the beck for about 150 yards westwardly from the footbridge, are the following boulders:—

1 ft. 8 in. ×	1 ft.	× 9 in.	Rounded.	Whinstone.
1 ft. 2 in. ×	1 ft.	× 9 in.	,,	Mountain limestone, containing *Productus giganteus.*
1 ft. 6 in. ×	1 ft. 1 in.	× 6 in.	Subangular.	Fine sandstone.
1 ft. 6 in. ×	1 ft.	× 7 in.	Rounded.	Dolerite.
1 ft.	× 6 in.	× 6 in.	Rounded to subangular.	Whinstone.
1 ft. 6 in. ×	1 ft.	× 1 ft.	Rounded.	Fine sandstone.
1 ft.	× 9 in.	× 6 in.	Subangular.	Whinstone.
1 ft. 4 in. ×	1 ft. 2 in.	× 7 in.	Angular.	Fine sandstone.
1 ft.	× 7 in.	× 10 in.	Subangular.	Dolerite.
1 ft.	× 6 in.	× 4 in.	Rounded.	Mountain limestone, containing coral.
3 ft. 5 in. ×	1 ft. 6 in.	× 10 in.	Angular.	Coarse, gritty sandstone.
1 ft. 4 in. ×	1 ft.	× 8 in.	Angular to subangular.	Whinstone.

Besides the above there were about 50 sandstones, 15 whinstones, 6 mountain limestones, and 5 ironstones, averaging 1 ft. × 8 in. The whole were much worn, and show no definite markings or striæ. Others, still smaller, may be seen, of red and grey granite, mica schist, red fine-grained sandstone (Permian?), lias showing *gryphœa incurva*, limestone, slate, various sandstones, and nodular ironstone from the estuarine series.

They are about 60 ft. above sea-level.

Most of these boulders rest upon clay overlying the Red Chalk, and some directly upon the chalk itself. The slopes of the gap are covered with the remnant of boulder clay, which has thus far escaped denudation. In former years the slopes of this ravine were dotted all over with large boulders, but these have been removed for road repairs, and it is only on account of the somewhat inaccessible character of the gorge at this point that these are allowed to remain.

Staintondale Cliffs (*Coast*).—About $\frac{3}{4}$ mile S.E. of Peak Hall, near Robin Hood's Bay, on the first ledge of the cliffs known as Staintondale Cliffs, is a boulder.

It is 3 ft. 5 in. × 3 ft. × 2 ft. Rounded and much weathered; longest axis N.W. and S.E.; no groovings or striations; Shap Fell granite; is about 250 feet above sea-level.

Lockington.—At Lockington, near Beverley, on Lord Hotham's estate, and on the farm of Mr. George Langdale, is a boulder. It protects an artesian well, about $\frac{1}{2}$ mile E. of the railway station.

It is at present 2 ft. 7 in. × 1 ft. 10 in. × 1 ft. 9 in., but has evidently been reduced in size; a coarse-grained grit, like Millstone Grit; is about 100 ft. above sea-level; originally rested on boulder clay, which covers the surrounding district.

Filey.—On the estate of Mr. Martin, and extending about 60 yards from the shore up the ravine, or at the bottom of what is known as Bentley's Beck, are the following boulders:—

2 ft. 6 in. × 1 ft. 3 in. × 1 ft.	Rounded.	Whinstone.
2 ft. × 1 ft. 9 in. × 1 ft. 6 in.	Subangular.	Sandstone.
2 ft. × 1 ft. 1 in. × 9 in.	Rounded.	Whinstone.
1 ft. 6 in. × 1 ft. 4 in. × 1 ft.	"	Mountain limestone.
1 ft. 9 in. × 1 ft. 6 in. × 1 ft. 2 in.	"	Sandstone.
2 ft. 7 in. × 1 ft. 4 in. × 1 ft. 3 in.	Subangular.	Whinstone.
1 ft. 11 in. × 1 ft. 1 in. × 1 ft.	Rounded.	Sandstone.
1 ft. 8 in. × 1 ft. × 9 in.	Subangular.	Whinstone.
1 ft. × 10 in. × 10 in.	"	Sandstone.

No striæ visible; about 30 ft. above sea-level; all are more or less imbedded in the clay, save those which have rolled down from their former positions.

At the mouth of the ravine were observed the following boulders:—

2 ft. 3 in. × 2 ft. 2 in. × 1 ft. 9 in.	Subangular.	Whinstone.
1 ft. 8 in. × 1 ft. 5 in. × 1 ft. 1 in.	Rounded.	"
2 ft. 6 in. × 1 ft. 11 in. × 1 ft. 4 in.	"	"
1 ft. 9 in. × 1 ft. 8 in. × 1 ft. 6 in.	"	Coarse grit.
1 ft. 9 in. × 1 ft. 2 in. × 1 ft. 1 in.	"	Whinstone.
1 ft. 4 in. × 1 ft. 2 in. × 1 ft. 1 in.	"	Dolerite.
1 ft. 11 in. × 1 ft. 6 in. × 1 ft. 4 in.	"	Whinstone.
3 ft. 4 in. × 2 ft. × 1 ft. 7 in.	Angular.	Hard red sandstone.
2 ft. 10 in. × 2 ft. 6 in. × 1 ft. 4 in.	Subangular.	Whinstone.
2 ft. 7 in. × 1 ft. 11 in. × 1 ft. 8 in.	Rounded.	Very coarse grit.
2 ft. × 1 ft. 11 in. × 1 ft. 3 in.	Subangular.	Hard sandstone.
2 ft. 7 in. × 2 ft. × 1 ft. 2 in.	Rounded.	Dolerite.
2 ft. 1 in. × 1 ft. 6 in. × 1 ft. 1 in.	"	Estuarine sandstone.
3 ft. × 1 ft. 10 in. × 1 ft. 4 in.	"	Whinstone.
2 ft. 6 in. × 2 ft 3 in. × 1 ft. 10 in.	"	Mountain limestone, full of corals, &c.

In addition there were measured 7 whinstones and 2 sandstones, averaging 1 ft. 6 in. × 1 ft. 4 in., and 10 whinstones and 4 sandstones, averaging 1 ft. 2 in. × 1 ft. 10 in., principally subangular.

The whole of these boulders have been removed to their present positions from the coast in the immediate vicinity, and will be used as backing for the new wooden breakwater in construction by Mr. Martin at the south part of Filey. The boulder clay here is of great thickness, and the small stream has cut its way through it, forming this ravine. The absence of granite boulders is accounted for, after inquiry, by their selection for the ornamentation of gardens.

Seamer (*near Scarborough*).—Seamer gravel-pit, in the parish of Seamer, near Scarborough, on the estate of Lord Londesborough, is situated about 3 miles to the south or south-west of Scarborough, and about 2 miles east of Seamer village, adjoining Seamer station, N.E. Railway. This pit is about 20 acres in extent, with an average depth of 12 ft.; during the time of excavation the following boulders were found: The largest at present in the pit is 4 ft. 8 in. × 2 ft. 8 in. × 1 ft. thick; angular, but no ice markings. There are 10 boulders averaging 3 ft. × 2 ft., 4 of which are 3 ft 2 in × 2 ft. 1 in. × 1 ft. 8 in.; rounded whinstone; no striation; and 4 averaging 3 ft. 4 in. × 3 ft. 1 in. × 2 ft.; composed of different kinds of sandstone; angular. One 3 ft. 10 in. × 2 ft. 7 in. × 2 ft.; angular; fucoid sandstone; estuarine; is crumbling away from exposure; and one 3 ft. 4 in × 3 ft. × 1 ft. 3 in.; rounded; mountain limestone; no striation on surface. There are 40 more, principally composed of sandstone, averaging 2 ft. × 1 ft. × 1 ft.; 8 of these are more or less angular blocks of whinstone; no striation. A short distance away are 31 boulders, averaging 2 ft. 2 in. × 1 ft. 6 in. × 1 ft.; part of these are rounded; in some instances showing faint traces of striation. Scattered and in heaps are 64 composed of grits to fine-grain compact sandstone, 56 of which average 1 ft. 2 in. × 1 ft. 1 in. × 11 in., and 8 are rounded whinstone; no striation. Two others are iron grey granite, averaging 1 ft. 6 in. × 1 ft. 7 in. × 1 ft.; rounded; no striæ.

NOTE.—The drift rests upon the Coralline Oolite, which appears to have been denuded away, leaving several harder lumps projecting into the drift. These were met with, and had to be removed to make room for the temporary railway. The whole extent of this drift bed is about 60 acres. Generally speaking, the main of the boulders were found on or towards the north face of the drift, which also contained the roughest gravel. To the south-east the gravel gradually gets smaller, more decayed, and rotten.

On the estate of Lord Londesborough, in the parish of Seamer, about 2½ miles S.W. of Scarborough, there is a boulder at the bottom of an old quarry in Limekiln Field on Eastfield Farm, occupied by Mrs. Eldines.

It is 3 ft. 1 in. × 2 ft. 9 in. × 2 ft. 1 in.; angular; there are wide hollow groovings in the direction of its longest axis; dark blue whinstone; about 200 ft. above sea-level.

This quarry was formerly worked for Oolite Limestone. It is capped by about 4 ft. of boulder clay, a good section of which is exposed. This boulder has doubtless rolled from the top to its present position.

Near Eastfield House, about ¼ mile due east of Seamer railway station, is a boulder.

It is 2 ft. 8 in. × 2 ft. 2 in. × 1 ft. 7 in.; rounded; has been moved; a light brown sandstone, resembling the moor grit; about 150 ft. above sea-level; was found in a ridge of gravel running north-westerly.

On Eastfield Farm, about 2 miles S. of Scarborough and about ½ mile E. of Seamer railway station, are the following boulders:—

2 ft. × 1 ft. 9 in. × 1 ft. 4 in.	Subangular.	Whinstone.
2 ft. 1 in. × 1 ft. 5 in. × 1 ft. 1 in.	Angular.	,,
2 ft. 2 in. × 1 ft. 9 in. × 1 ft. 1 in.	Rounded.	Sandstone.
1 ft. 8 in. × 1 ft. × 1 ft.	,,	,,
2 ft. 11 in. × 1 ft. 10 in. × 1 ft. 2 in.	Subangular.	Whinstone.

No striæ visible; they have been removed from the adjoining fields; about 150 ft. above sea-level.

NOTE.—There are many other boulders scattered over the farm, composed of whinstone and sandstone, in the proportion of 3 to 2; the sandstone resembles the moor grit.

Kilnsea (*E. Riding*).—Mr. John Cordeaux, M.B.O.U., Great Cotes, Ulceby, Lincolnshire, records an erratic. On the beach about 500 yards south of Kilnsea Beacon, Kilnsea, near Patrington, was a boulder, but now removed to the lawn of Dr. Hewetson's garden, Easington.

It is 3 ft. 2 in. × 2 ft. 4 in.; subangular; long-shaped; longest axis N.W. and S.E.; there are deep striæ or groovings in direction of longest axis; Shap Fell granite; it rested upon blue clay, had been probably exposed only a few days, and was *in situ* when discovered by himself and Dr. Hewetson on November 10, 1889.

NOTE.—This boulder has the value of being the only one found hitherto so far south on the Yorkshire Coast near Spurn Point.

Easington (*East Riding*).—Mr. John W. Stather, Hull (Hon. Sec. Hull Geological Society), describes the following group of erratics:—On the half-mile of beach opposite Easington, about six miles from Spurn Point, and at the southern end of Dimlington 'high land' (boulder clay cliffs) are many boulders, twelve of the largest being measured, viz.:—

A.	4 ft. 2 in. × 2 ft.	× 1 ft. 6 in.		G.	5 ft.	× 3 ft.	× 2 ft.
B.	4 ft. 3 in. × 3 ft.	× 2 ft. 6 in.		H.	5 ft.	× 3 ft. 6 in.	× 2 ft.
C.				I.	4 ft. 6 in.	× 3 ft.	× 2 ft. 6 in.
D.	2 ft. 3 in. × 2 ft.	× 1 ft.		K.	4 ft. 3 in.	× 4 ft.	× 2 ft. 6 in.
E.	3 ft. 3 in. × 2 ft. 6 in.	× 1 ft. 6 in.		L.	4 ft. 6 in.	× 3 ft.	× 2 ft. 6 in.
F.	3 ft. 6 in. × 3 ft. 6 in.	× 2 ft.		M.	1 ft. 6 in.	× 1 ft.	× 4 in.

Are all subangular; the longest axis of A, B, and H are N.W. and S.E., those of G and L being E. and W.; K and F are striated, and D more decidedly so; they are below high-water mark, and rest upon the basement clay, in which they are partly imbedded; others have probably fallen from the purple clay which here forms the upper part of the cliff.

Laithkirk (*North Riding*).—Rev. W. R. Bell, Vicar of Laithkirk, states that at Laithkirk, near Mickleton, there is a large boulder. It was found on the north bank of the Lune, immediately below the church, and is now set up in the Laithkirk Vicarage gardens. It is 2 ft. 8 in. × 1 ft. 9 in. × 2 ft. 6 in.; it is roughly cuneiform in shape; subangular; has been moved; Shap Fell granite; its original site was 700 feet above sea-level; no striæ visible.

Wath (*North Riding*).—Dr. T. Carter Mitchell, Topcliffe, Thirsk, reports that on the Coldstone Farm, Middelton Quernhow Estate, and parish of Wath, is a boulder. It is on the side of the road from Middleton Vicarage to Ainderby Quernhow, and about halfway between.

It is 2 ft. 1 in. × 1 ft. 5 in. × 1 ft. 3 in.; subangular; has been moved: there are no ice markings, but it is curiously grooved by weathering; is about 200 ft. above sea-level; it is isolated; rests on drift, overlying Triassic deposits.

Mulgrave Park, near Whitby.—Dr. R. Taylor Manson, Darlington, records a boulder in Mulgrave Park, 4 miles N.W. of Whitby; nearest station is Sandsend, on the Saltburn and Whitby line. It is on the north bank of a stream running east between the Old Castle of Mulgrave and a spot known as the 'Hermitage.' It is 3 ft. in diameter; rounded; no striæ or groovings; Shap Fell granite; about 100 feet above sea-level; it is isolated in the rivulet to which it has probably rolled down from the clay above; the stream is cut through lias shale.

Balby, near Doncaster.—In the Balby brickyards, near Doncaster, the following group of boulders are recorded by Mr. E. Moor:—

Largest boulder, 2 ft. × $1\frac{1}{2}$ ft. × 1 ft.; striations numerous on the top, but faint, and in direction of short axis.

Smallest boulder, 2 in. × $1\frac{1}{2}$ in. × 1 in.; fossiliferous limestone; girth 16 in.; length 10 in.; striations numerous, but faint, about 1 in. long in direction of long axis; granite block, angular; girth 12 in. × 8 in. long. The boulders are rounded and subangular.

The group extends over about 5 acres; small ones very numerous. These boulders are surrounded by a thick deposit of clay, which has been excavated to the depth of 50 ft., and are met with at various depths in the clay.

Winestead.—Wm. Barugh, Winestead, Hull, describes two erratics. About half a mile N. of the railway station, near site of former hall, about fifty yards from highway, is a boulder, 4 ft. 2 in. × 3 ft. 6 in. × $1\frac{1}{2}$ ft. It is subangular; it has been moved; there is a groove $\frac{1}{2}$ in. deep and length of the stone. The boulder is striated at the top in direction of longer axis; it is whinstone; probably 20 ft. above the level of the sea; it is isolated, resting on boulder clay.

In the paddock at Winestead, belonging to the Park Farm, is a boulder 2 ft. 8 in. × 2 ft. 2 in. × 1 ft. It is much rounded; it has been moved; it is mountain limestone; about 20 ft. above sea-level; isolated; it rests on the surface of the ground.

Sixteenth Report of the Committee, consisting of Drs. E. HULL *and* H. W. CROSSKEY, Sir DOUGLAS GALTON, Professor G. A. LEBOUR, *and* Messrs. JAMES GLAISHER, E. B. MARTEN, G. H. MORTON, W. PENGELLY, JAMES PLANT, J. PRESTWICH, I. ROBERTS, T. S. STOOKE, G. J. SYMONS, W. TOPLEY, TYLDEN-WRIGHT, E. WETHERED, W. WHITAKER, *and* C. E. DE RANCE (*Secretary*), *appointed for the purpose of investigating the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations.* (*Drawn up by* C. E. DE RANCE, *Reporter.*)

YOUR Reporter regrets to record the death of Mr. R. W. Mylne, C.E., F.R.S., an original member of your Committee, being appointed in 1874 at Belfast, where he assisted in drawing up the schedule of questions circulated by your Committee. Pressure of professional engagements prevented him taking charge of a district, but he was always ready to give the results of his life-long experience to elucidate a point or assist the work of your Committee. In 1839, more than half a century ago, he contributed to the Institution of Civil Engineers the first paper published in their Proceedings upon Artesian Wells. He was probably the first civil engineer who applied geological investigation to the elucidation of practical problems in engineering. He early saw the great importance of accurate levels being taken of the junction of permeable and impermeable strata, and of the points at which it was proposed to sink wells. At his own cost he contoured the whole of the metropolitan area years before the appearance of the Ordnance Survey contoured maps, and published his Geological Map of the same area, while the Government Geological Survey were still engaged in the west of England.

In his sections of the London Strata, published in 1850, he was the pioneer of the work now being done by your Committee in collecting well sections; and as regards the Metropolitan area, he laid the basis of our present knowledge of the nature of the water-bearing strata and their levels, in which latter information subsequent workers have often been exceedingly sparing.

As hydraulic consulting engineer to the War Office, his geological knowledge enabled him in 1866 to confidently recommend the construction of the Horse-shoe Fort Well, the first of the Spit Head wells, which were the first wells sunk in the sea to obtain fresh water. In the necessary examination of the Isle of Wight preceding his Report, your Reporter acted as his assistant.

In 1866, complying with instructions of 'the Royal Commission on Water Supply,' of which the Duke of Richmond was chairman, he worked out the relation of flood-waters absorbed by the 'swallow holes' in the basin of the river Colne, and their reappearance as the New River Springs in the basin of the Lea.

In 1880, acting for the united opposition of the London Water Companies against the Government proposal to buy up the water companies, he worked up all that was known as to underground water in the metropolitan area. This evidence, unfortunately for our present knowledge, was never reached, but its general purport went to show that no large supply of underground water can be met with in a moderate radius of London without diminishing the minimum, or dry-weather, flow of the streams.

More than half a century has elapsed since the publication of Mr. Mylne's first paper. Since then artesian and ordinary wells have been sunk in all directions, and previously to that date, doubtless, numerous others had been constructed in various parts of the country, some of them dating back to the Middle Ages. Your Committee would wish to specially urge the Associated Provincial Societies to discover and preserve any early records of the sinking of wells that may be found in county, municipal, borough, or family documents, in county histories, and in the more recent papers of business firms using considerable quantities of water. Amongst the latter it is highly probable that numerous records of the daily or weekly variation in height of the water in their wells have been preserved.

Continuous daily records of the height of the water of existing wells are much wanted, with the height of the surface above the Ordnance Survey datum. The height above datum of many of the wells, in reference to which information has already been published in the preceding fifteen Reports, would much add to the value of the existing record; such additional information could easily be got by many of the provincial societies.

The record of water-level in the well at Odsey Grange, commenced by Mr. H. George Fordham, F.G.S., in November 29, 1878, unfortunately terminated on October 1, 1888, through his having to live abroad. Two other series of observations exist in the same area, viz. at Therfield Rectory, where a monthly record was commenced by the Rev. J. G. Hale on January 1, 1883, and is now continuing, and at Barley, where monthly observations were made by the late Mr. John Pearce, from January 1, 1864, to October 1, 1886.

West			East
WELL	Odsey Grange, 2½ miles	Therfield Rectory, 4½ miles	Barley
Surface level	265 ft.	506 ft.	305 ft.
Depth of well	104 ft.	276 ft.	165 ft.
Well + or −O.D.	161 ft. (+O.D.)	230 (+O.D.)	140 (+O.D.)
Nearest spring	E. of Ashwell, 1¾ mile off	Litlington (Camb.), 4 miles off	Melbourn (Camb.), 4 miles off
Height of springs	150 ft.	150 ft.	150 ft.

The springs rise on the outcrop of the horizon of the Totternhoe limestone, and feed the western branch of the Cam (or Rhee). Barley and Odsey are in the Cam Valley, Therfield on the ridge between it and the slope to the south draining into the Thames; the surface flow is in that direction, but the underground flow to the N.N.W. finding the Cam springs; these rise but a few feet after the wettest season, but the variation of the water-level in the wells to the south is considerable, the maximum difference between the highest and the lowest level being $44\frac{1}{2}$ feet at Odsey, 78 feet at Barley, and $64\frac{3}{4}$ at Therfield; the greatest difference in any one year (April to March) being respectively $39\frac{1}{2}$ feet (1882–83), 52 feet (1865–66), and 34 feet (1884–85). Mr. Fordham has selected for his daily record at Odsey the levels on the first of the month, starting April 1, the date about which the autumn and winter rains produce the maximum elevation. He also gives the mean monthly level per year and per series of years. The rainfall returns terminate three months before the well-level, viz. on December 31.

The rainfall year ending three months before the water-level year, affords a convenient method of comparison, the effect of the percolation of rain being exceedingly slow. The highest level to which the water rose was attained twice (50 feet), on March 22, 1881, and February 27, 1883; the lowest level reached, $5\frac{1}{2}$ feet, was on December 16, 1884, giving a seasonal variation of $44\frac{1}{2}$; the greatest seasonal variation in one twelve months was 1882–83, when it amounted to 40 feet (50—10 feet); the rise was distributed over exactly four months, viz. from October 27 to February 27. In 1879 and 1883 the final winter rise was very rapid, amounting to 10 to 13 inches in 24 hours in February, or a maximum of about half an inch per hour. The summer fall is generally long and gradual; in June 1886 an abnormal rise of 8 feet, commencing on May 25, was due to the exceptional rain of the preceding May, which amounted to 4·71 inches. An abnormal summer rainfall of 20·37 inches, from April to September 1879, caused the water to rise all the summer, culminating in August, and, with a dry autumn, reached its normal autumn level in October. The conditions in these cases must have been unusual; the ordinary summer rain, however heavy, percolates but little; much doubtless depends on the amount of moisture held in the air at the time. Comparison of the three wells shows close parallelism in the curves of movement, but they are later in the deeper wells in Therfield and Barley than at Odsey.[1]

LANCASHIRE.

In previous reports, sections were described in the Keuper marls of the Fleetwood district, on the east side of the River Wyre, containing 340 feet of solid rock salt. The Garstang sandstone to the east has been referred to as of Permian age, and referable to the Hawcote sandstone of the Furness district. These are said to have been recently bored through at Walney Island by the North of England Rock Boring Company, of which Mr. Vivian is director, and extensive deposits of rock salt found. It is of interest to observe that at the southern horn of Morecambe Bay thick salt beds of Keuper Triassic age occur, while similar beds occur on the opposite shore of Permian age, and contemporaneous with those of the east coast between the mouths of the Tees and Tyne. In this relation the following boring is of great interest, penetrating Permian sandstone a few hundred yards east of the salt marls of Presall, and probably separated from them by a fault.

[1] Further details and plates will be found in the *Trans. Herts Nat. Hist. Soc.*, vol. vi. parts i. and ii., July and September 1890.

Boring at Presall End pumping station of the Fleetwood Salt Co. Communicated by Mr. Wethered, senior.

No. 17 *Boring.*

Ft.	in.		Ft.	in.
9	0	Soil 1 foot 6 in., loamy sand 5 ft. 6 in., sand and gravel 2 ft. 0 in.	9	0
44	9	Boulder clay 31 ft. 0 in., running sand, 4 ft. 9 in.	35	9
112	2	Strong red sandstone, hard girdles (water)	67	5
119	5	Soft light sandstone (water)	7	3
129	11	Strong red sandstone (water)	10	6
130	5	Very hard girdles	0	6
149	11	Soft yellow sandstone (water)	19	6
183	11	Strong yellow sandstone, hard partings (water)	34	0
249	3	Hard red sandstone, soft partings, 2″ of red marl	65	4
		Mild red sandstone (water)	49	0
		Very soft partings	2	0
355	3	Hard red sandstone, soft partings (water)	52	0
		Soft red sandstone, hard girdles (water)	13	0
		Strong sandstone, hard girdles (water)	19	3
		Very hard white sandstone (water)	2	4
418	8	Hard red sandstone, hard girdle, white shale parting	28	10
		Hard red sandstone, white girdles	26	0
		Hard red sandstone, hard white girdle, partings (water)	46	0
		Strong red dark metal	5	2
499	6	Very hard white sandstone	3	8
		Strong red sandstone, hard white girdle	25	8
		Strong red metal	4	8
544	2	Strong red sandstone	14	4

Section of well sunk at Fleetwood in 1860 *by the Royal Engineers.*

Ft.	in.		Ft.	in.
41	10	Gravel and sand	41	10
59	2	Rough gravel	17	4
		Boulder clay	17	4
		Gravel bored	2	0
88	5	Boulder clay (marl)	9	11
440	9	Mottled marl	352	4
463	10	Fine blue marl	23	1
478	6	Mottled marl	14	8
480	7	Marl	2	1
492	0	Soft gritty matter	11	5
501	3	Gritty matter	9	3
523	9	Hard gritty matter	22	6
534	10	Red and blue marl	11	1
550	0	Fine blue marl	15	2
559	0	Marl	9	3

In Lancashire and Cheshire the borings collected by your reporter have thrown much light upon the age of the intermediate beds lying beneath the Triassic Pebble Beds and the Coal-measure, which have been penetrated in numerous borings in these districts already described. Careful comparison of the very numerous borings that have now been collected point to the correctness of the late Mr. Binney's views as to the absence of the Lower Mottled Sandstone in South Lancashire, the Pebble Beds on the eastern end of the Mersey Valley resting on the Permian fossilific marls with limestone lying on fine soft sandstone, with occasional hard coarse beds, and occasionally another thick marl-bed. Extensive denudation of the Permian beds took place, not only before the deposition of the Bunter Pebble Beds, but during the deposition of the Permians themselves, lines of erosion occurring at more than one horizon, represented by bands of exceedingly coarse sand and conglomerate; westward the denudation has been extreme, and such of the Permian strata as have been preserved are probably present through being thrown down by contemporaneous faulting. The section at Gateacre in Childwall Vale was given in the last report. The boring was made for the Liverpool Corporation Waterworks; it is situated 500 yards from the Bellevale boring, and 1,100 yards from the Netherlee boring of the Widnes Waterworks, both of which are in soft millet-seed-grained red sandstone; but at Gateacre the beds, though occurring between these two wells, both of which yield exceedingly large supplies of water, were not water-bearing, and belong to the Pebble Beds, which rest directly on the Coal-measure at a depth of 435 feet, the latter being bored into a further 5½ feet.

The Halewood boring of the Cheshire Lines Railway, given in the last report, in which 276 feet of marls occurred, specimens of which were examined microscopically by the late Mr. John A. Phillips, F.R.S., and found to contain a substance resulting from the decomposition of felspars, must now be referred to the Permian marls. This view is supported by the following section at Hale, three miles south of Halewood, and like it carried out by Messrs. Timmins of Runcorn.

Feet.		Feet.
	Turf and soil	4
68	Soft red sandstone	64
168	Fine bright red sandstone	100
235	Red marl	67

Mr. A. Timmins, C.E., F.G.S., very properly points out that the great thickness of the Permian marl at Halewood may be deceptive, and due to the great faults to which it owes its preservation.[1]

Through the courtesy of Mr. D. M. F. Gaskin, M.I.C.E., Engineer to the St. Helens Corporation, I have had an opportunity of examining the cores brought up from their two last borings, described in the last Report. The section of the Kirby well there printed is taken from the beds passed through in the 'Permanent Well,' to a depth of 147 feet; the details following give the strata passed through in the adjacent boring from the bottom of the 'Pilot Shaft,' in which an error occurs of 50 feet; '352¼ red sandstone with pebbles 52 feet,' should read, '202½ red sandstone with pebbles 102 feet.'

The Kirby Waterworks consist of two wells, 150 feet in depth, connected by an adit, at from 135 to 144 feet from the surface, or 9 feet in height by 6 feet in width. The wells are 31 feet apart, the Pilot well being 31 feet to the N.N.W. of the Permanent well. From the bottom of the Pilot well a boring was carried 360 feet and 6 inches, or 510 feet 6 inches from the surface. The first 80 feet had a diameter of 24 inches, the remainder being 18 inches. The following is the section of the Pilot well and boring:—

Ft.	in.		Ft.	in.
1	6	Top soil	1	6
5	0	Clay	3	6
7	0	Red sand	2	0
13	3	Red sandstone	6	3

[1] *Proc. Liverpool Geol. Soc.* 1888–9.

Ft.	in.		Ft.	in.
13	6	Grey sandstone	0	3
14	9	Sandy marl	1	3
16	0	Red sandstone	1	3
27	0	Red sandstone with pebbles	11	0
32	0	Grey and red sand, small pebbles	5	0
32	4	Sandstone	0	4
55	2	Red sandstone with pebbles	22	10
95	2	Red sandstone	40	0
120	2	Red sandstone with few pebbles	25	0
123	2	Red sandstone with white patches	3	0
130	2	Red sandstone with few pebbles	7	0
137	2	Red sandstone	7	0
145	2	Red sandstone, few pebbles	8	0
148	2	Variegated sandstone	3	0
160	0	Red sandstone with pebbles	11	0
175	0	Red sandstone	15	0
184	0	Close-grained red sandstone	9	0
254	0	Red sandstone with pebbles	70	0
254	6	Variegated sandstone	0	6
261	6	Red sandstone	7	0
262	0	Variegated sandstone	0	6
300	0	Red sandstone with pebbles	38	0
300	3	White sandstone	0	3
402	3	Red sand with pebbles	102	0
402	6	Red marl	0	3
442	6	Red sand, pebbles, and white sand	40	0
510	6	Red sandstone with pyrites	68	0

In this boring the first $442\frac{1}{2}$ feet is referable to the Triassic Pebble Beds, the last 68 feet belongs to the beds occurring between the Pebble Beds and the Coal-measure at Winwich, Parkside, and Collins Green, containing iron pyrites, and underlying marls of Permian age. The wells were commenced in June 1886, and the boring was completed in September 1887. The surface level is 100 feet above Ordnance datum, the normal level of the water is 91 feet above the same datum, and is reduced by pumping to 57 feet, and is kept at that level, having a column of 107 feet of water in the well; the yield is two million gallons per day, but if the water be pumped down to 9 feet below Ordnance datum, the yield is not less than four million gallons. Water came into the well freely from 28 feet from the surface, the water apparently coming in from the south-east. The wells and tunnels yielded nearly a million gallons daily before the boring was commenced in May 1887. The supply of the well and boring may be considered to be wholly from the Bunter Pebble Beds.

The Knowsley pumping station consists of three wells, connected by adits and bore-holes from two of them. The most southern is called the Permanent well; it is $10\frac{1}{2}$ feet in diameter, and 173 feet in depth; from 141 feet to 164 feet is a chamber or adit, 23 feet by 6 feet, and 30 feet in length, ranging N.N.E. to the Pilot well. The surface level of the Pilot well is a foot below the Permanent well; it is 171 feet in depth and $10\frac{1}{2}$ feet in diameter; from the bottom extends a boring 250 feet in depth; 321 feet from the surface; an accident happening at this depth, another well and boring was carried out, known as the Six-feet well. The latter is the diameter named, and 161 feet in depth; a boring was carried from the bottom, a depth of 526 feet, or 687 feet from the surface. The latter well and boring were entirely carried out in the year 1884. The details of the section are given in the fifteenth Report. The details of the first two shafts agree, but do not correspond with the section disclosed in the Six-feet shaft, and point to a fault between it and the Pilot well. The two wells are connected by an adit at a depth of 155 to 161 feet; the level was 6 feet by 5 feet, and 30 feet in length, ranging N.N.W. from the Pilot shaft; no information is given as to whether the fault was noticed in driving the heading. The yield of these wells is about one and a half millions daily, the chief supply being derived from a sound bed one foot in thickness, and the soft beds below it, occurring at 478 feet from the surface; this water supply may be considered as wholly coming from the Permian or Collyhurst sandstones. The surface level of the ground is 140 feet above the Ordnance datum, its first rest level was 78 feet above Ordnance datum, its present rest level is 72 feet.

The following are the details of the section in Pilot shaft:—

Ft.	in.		Ft.	in.
1	6	Black loam	1	6
2	9	Grey sand	1	3
5	3	Brown marl	2	6
		Yellow shale	0	6
		Red shale	1	6
8	0	Yellow shale	0	9
20	0	Red sandstone	12	0
21	0	Yellow sandstone	1	0
50	0	Red sandstone	29	0
110	0	Red sandstone	60	0
140	0	Close-grained red sandstone	30	0
163	0	Red sandstone with thin bands of yellow and grey sandstone	23	0
164	0	Yellow sandstone	1	0
171	0	Red sandstone (bottom of well)	7	0
174	0	Red sandstone, thin band of grey	3	0
179	0	Close-grained red sandstone	5	0
179	6	Red marl.	0	6
187	6	Red sandstone	8	0
196	6	Yellow sandstone	9	0
197	0	Red marl	0	6
261	0	Close-grained red sandstone	64	0
264	6	Red marl	3	6
273	0	Close-grained red sandstone	9	6
277	0	Red sand with thin yellow and grey	4	0
296	0	Grey sandstone	19	0
297	0	Red marl	1	0
306	0	Grey sandstone	9	0
321	0	Red sandstone, grey bands	15	0
323	0	Clay and marl with small pebbles	2	0
326	0	Red sand.	3	0
337	0	Red marl	11	0
346	0	Red sandstone	9	0
363	0	Grey sandstone with veins of red	19	0
383	0	Red sandstone.	20	0
421	0	Grey sandstone	38	0

The dip of the rocks is said to be 1 in 9, which would have carried the above beds to about 3 feet lower level in the six-feet well; instead of that being the case there is considerable variation, but chiefly in the lower portion. The upper 199 feet are doubtfully referable to the Bunter Pebble beds; the lower portion is certainly Permian, and the water obtained like that afforded by the Winwick borings of the Warrington Waterworks derived from that formation.

The following table of analyses of Permian marls and sandstone, made by Mr. A. Timmins, Assoc.Inst.C.E., F.G.S., is of much interest in relation to the question of the age of these beds:—

—	Depths	Insoluble Matter	Oxide of Iron and Alumina	Carbonate of Lime	Carbonate of Magnesium	Total
	Feet					
Halewood, C.L.R. Co.	287	93·07	1·31	3·66	2·24	99·28
" "	303	77·67	3·21	18·66	·00	99·54
" "	373	75·04	7·68	16·68	·07	99·47
Prescot, L. & N.W.R.	54	83·59	3·46	9·90	·91	97·86
Bootle, Liverpool	1,290	76·69	8·78	10·63	1·44	97·51
Knowsley, W.W.	170	95·78	1·60	1·53	·00	98·91
Winwick	228	63·70	4·12	19·32	11·97	99·11
Parkside, L. & N.W.R.	220	82·55	2·98	14·04	2·96	99·86
Baswich, Stafford	164	80·15	4·21	14·50	·00	98·88
" "	295	84·94	4·18	8·88	1·63	99·63
" "	425	39·18	3·96	55·56	·24	98·94
Shrewsbury Grammar School.	—	89·40	1·28	9·52	·00	100·20

Messrs. J. J. M. Worrall's Dye Works, Ordsall, Salford (88 *feet above Ordnance datum*).

Information from Messrs. Mather and Platt. Well about 1860, carried to a depth of 399 feet. No details known.

Ft.	in.		Ft.	in.
399	0	Details unknown	399	0
700	0	Red sandstone	301	0
701	0	Grey sandstone	1	0
744	0	Red sandstone	43	0
745	0	Grey sandstone	1	0
761	0	Red sandstone (base of trias)	16	0
910	0	Red marl	149	0
1,230	0	Red sandstone	320	0
1,236	6	Hard grey rock (coal measure)	6	6
		Red marl	(+)	

Abstract:—

Ft.	in.		Ft.	in.
761	0	New red sandstone	761	0
910	0	Permian marls	149	0
1,236	6	Permian sandstones	326	6
		Red marls	(+)	

Water-level is 80 feet below the surface.

Boring at Messrs. Groves & Whitnall's, Regent Road Brewery, Salford.

Information from Messrs. Mather and Platt. Surface 80 feet above Ordnance datum.

From Surface Ft.	in.		Thickness Ft.	in.
390	0	Pebble beds of the new red	390	0
548	0	Permian marls	158	0
662	0	Permian sandstones, coarse grained	114	0
666	0	Permian sandstones, very fine grained	4	0

When boring in the marl water stood in the bore-hole 40 feet from the surface, or at the same level as the water standing in the old well, at the other end of the works, executed in 1872 by Mr. Chapman, which was carried to the base of the Pebble beds, but stopped on reaching the Permian marls. When the latter were penetrated by Messrs. Mather and Platt the water rose 5 feet in twenty-four hours, and when 666 feet was reached it stood at 26 feet from the surface.

Messrs. Fryers & Co.'s Sugar Works, near Oxford Road.

Surface-level 120.

Ft.	in.		Ft.	in.
70	0	Well with heading and large chambers	70	0
114	0	Pebble beds	44	0
351	0	Red and varied marls, thin limestones	237	0
396	0	Coarse gravel and pebbles	45	0
420	0	Compact red and white sandstone	24	0
546	0	Red and purple marl with bands of limestone	126	0

Messrs. Deakin's Brewery, Ardwick, Manchester.

Information from Messrs. Chapman, Broughton. Surface-level about +150 feet Ordnance datum.

Ft.	in.		Ft.	in.	
		Well sandstone	35	0	
60	6	Soft red sandstone	25	6	131 ft. 6 in.
61	6	Fine red clay	1	0	
127	6	Soft, fine, and loamy red sandstone	66	0	
131	6	Very coarse red gritty sand	4	0	
167	0	Red clay	35	6	Permian marls, 167 ft. 6 in.
168	0	Loamy red sandstone	1	0	
183	0	Red clay and conglomerate	15	0	
199	0	Very loamy red sandstone	16	0	
204	0	Red clay	5	0	
207	0	Red sandstone	3	0	
227	6	Red clay	20	6	
231	6	Red clay	4	0	
257	6	Red and white clay mixed	26	0	
258	6	Conglomerate, with thin band of ironstone	1	0	
281	6	Red clay	23	0	
284	6	Conglomerate with pebbles	3	0	
299	0	Soft red clay	14	6	
362	6	Very fine loamy red sandstone	63	0	Collyhurst sandstone, 184 ft.
364	0	Coarse gritty red sandstone	2	0	
378	6	Fine bright soft red sandstone	14	6	
383	6	Very coarse red sandstone	5	0	
483	0	Soft and fine red sandstone	99	6	
489	2	Hard red clay with hæmatite bands in limestone	6	2	Coal measure, 6 ft. 9 in
489	9	Red and white clay	0	7	

Abstract of above:—

	Ft.	in.
Bunter sandstone	131	6
Permian marls	167	6
Permian sandstone	184	0
Coal measure	6	9
	489	1

Messrs. Holts' Brewery, Cheetham, Manchester.

Surface-level 170 feet above Ordnance datum. Well 90 feet in depth; made some years ago.

Ft.	in.		Ft.	in.	
60	0	Well, details not known	60	0	
90	0	Well { sandstone	30	0	
143	0	Boring { sandstone	53	0	
157	0	Sandstone with pebble	14	0	P. beds, 258 ft.
163	0	Red marl	6	0	
240	0	Sandstone hard	77	0	
258	0	Sandstone softer	18	0	
368	0	Red marl	110	0	
370	6	Grey conglomerate	2	0	
399	0	Red marl	29	0	Permian marls 161 ft.
408	0	Red marl with grey bands	9	0	
408	6	Hard grey rock	0	6	
419	0	Red marl	10	6	
526	0	Red sandstone	107	0	
			526	0	

Abstract:—

	Ft.	in.
Sandstone, pebbly or hard	258	0
Marls, some sandy bands	161	0
Sandstone	107	0
	526	0

At 368 feet the water stood at 80 ft. 8 in. from the surface, at 419 feet it stood at 78 ft. 6 in.

Abstract of Mr. Wood's boring at Medlock Vale, East of Manchester.

Ft.	in.		Ft.	in.
26	6	Glacial drift	26	0
49	6	Triassic sandstone	23	0
295	0	Permian marl, with limestone and gypsum	245	6
718	10	Permian sandstone	423	10
862	5	Coal measures	143	7

The details of the following twelve well-borings are given by Mr. Arthur Timmins, Assoc.Inst.C.E., F.G.S., of Messrs. Timmins & Sons, Bridgewater Foundry, Runcorn.

Section of Boring for L. and N.W. Railway, Heaton Chapel.

Strata	Progressive Depths		Thickness of Strata	
	Ft.	in.	Ft.	in.
Boulder clay	10	0	10	0
Permian sandstone	75	0	65	0
Permian marl	85	0	10	0
Permian sandstone	315	0	230	0

Water 60 feet down.

Section of Boring for L. and N.W. Railway Co., Heaton Norris.

Strata	Progressive Depths Ft.	in.	Thickness of Strata Ft.	in.
Top drift	18	0	18	0
Red rock	144	0	126	0
Red marl	156	0	12	0
Red rock	181	0	25	0

Section of Boring at Messrs. Melland & Coward's, Heaton Mersey.

Strata	Progressive Depths Ft.	in.	Thickness of Strata Ft.	in.
Made ground	13	0	13	0
Pebble-bed sandstone	110	0	97	0
Red marl	113	0	3	0
Brown rock	115	0	2	0
Red marl	130	0	15	0
Soft rock	139	0	9	0
Red marl	144	0	5	0
Dark red rock	157	0	13	0
Permian marl	189	0	32	0
Limestone	190	0	1	0
Red marl	215	0	25	0
Vein of limestone	215	6	0	6
Red marl	253	0	37	6
Fine gravel (conglomerate)	255	0	2	0
Red marl	278	0	23	0
Red sandstone	400	0	122	0
Red marl	402	0	2	0
Red sandstone	606	6	204	6

Water overflows at surface at the rate of 2,160 gallons per hour.

Cheshire.

Section of Boring for L. and N. W. Railway, Edgeley.

(Ordnance datum, 180+.)

Strata	Progressive Depths Ft.	in.	Thickness of Strata Ft.	in.
Drift clay 26 ft., sand and gravel on rock	75	0	75	0
Upper Bunter sandstone	101	0	26	0
Pebble beds, with pebbles	230	0	129	0
Red marl	232	0	2	0
Coarse pebbly rock	287	6	55	6
Fine dark rock	324	6	37	0
Marl bed	326	6	2	0
Red rock	333	0	6	6
Marl bed	335	0	2	0
Hard pebbly rock	407	0	72	0
Marl bed	408	0	1	0
Hard coarse pebbly rock bed at 480 ft.	489	0	81	0
Marly rock	491	0	2	0
Good red rock	525	0	34	0

Water levels itself at 32 feet down.

Section of Boring for Messrs. Battersby & Co., Hemshaw Lane, Stockport.

Strata	Progressive Depths		Thickness of Strata	
	Ft.	in.	Ft.	in.
Sand	37	0	37	0
Clay	77	0	40	0
Gravel	87	0	10	0
Rock	106	0	19	0

From information by Messrs. Battersby & Co.

Section of Boring for Mr. Frederic Robinson, Unicorn Brewery, Stockport.
(Ordnance datum, 140 + .)

Strata	Progressive Depths		Thickness of Strata	
	Ft.	in.	Ft.	in.
Permian marl (fossils)	51	0	51	0
Fine gravel (conglomerate)	52	6	1	6
Red sand	56	0	3	6
Red marl	77	0	21	0
Sandy marl	84	0	7	0
Red sandstone (M.S.G.)	152	0	68	0
Red marl	153	0	1	0
Red sandstone	159	0	6	0
Red marl	200	0	41	0
Sandy marl	214	0	14	0
Red sandstone	260	0	46	0

Water level, 26 feet from top.

Section of Boring at Messrs. J. Cheetham & Sons', Club House Brewery, Stockport.

Strata	Progressive Depths		Thickness of Strata	
	Ft.	in.	Ft.	in.
Well (no data)	—		65	0
Red marl	210	0	145	0
Conglomerate	211	6	1	6
Sandy marl	216	0	4	6
Red sandstone	241	0	25	0
Red marl	246	0	5	0

Water level 42 feet from top.

Stratigraphical Section of Boring for Messrs. Micholls, Lucas & Co., Kingston Mill, Stockport.

Strata	Progressive Depths		Thickness of Strata	
	Ft.	in.	Ft.	n
Gravel and stones	11	0	11	0
Soft red sandstone	88	0	77	0
Red marl	118	0	30	0
Soft red sandstone	152	0	34	0

Section of Boring for Mr. Joseph Worrall, Windsor Castle Brewery, Stockport.

(Ordnance datum, 238.)

Strata	Progressive Depths		Thickness of Strata	
	Ft.	in.	Ft.	in.
Brown clay	70	0	70	0
Sand and gravel	90	0	20	0
Permian marl	122	0	32	0
Limestone	123	0	1	0
Permian marl	125	0	2	0
Limestone	127	0	2	0
Permian marl	148	0	21	0
Permian sandstone	198	0	50	0
Sandy marl	205	0	7	0
Permian marl	233	0	28	0
Fine-grained sandstone	253	0	20	0
Coarse-grained sandstone	272	0	19	0

Water level, 73 feet from top.

Section of Boring at the Gas Works, Bollington.

Strata	Progressive Depths		Thickness of Strata	
	Ft.	in.	Ft.	in.
Boulder clay	51	6	51	6
Gravel	56	0	4	6
Fine brown clay	100	0	44	0
N. R. { Pebble beds	322	0	222	0
N. R. { Red marl	330	0	8	0
N. R. { Pebble bed sandstone	400	0	70	0
P. { Red marl	436	0	36	0
P. { Fine bright red sandstone	504	0	68	0
P. { Red marl	505	0	1	0

Water stood at 136 feet below.

Section of Boring at Messrs. Syddall Bros'. Print Works, Chadkirk.

(Ordnance datum, 200 + .)

Strata	Progressive Depths		Thickness of Strata	
	Ft.	in.	Ft.	in.
Gravel	10	0	10	0
Dark grey shale, or soapstone	380	0	370	0
Millstone grit	465	0	85	0
Black shale	512	0	47	0
Millstone grit	550	0	38	0
Dark grit	577	0	27	0
Black shale	602	0	25	0

Water overflows at least 20 feet above surface.

Section of Boring for Messrs. Richardson & Goodall, Altrincham.

(Ordnance datum, 125+.)

Strata	Progressive Depths Ft.	in.	Thickness of Strata Ft.	in.
Well (no data)	21	0	21	0
Fine brown sand	46	0	25	0
Sandy clay	49	0	3	0
Fine brown sand	54	0	5	0
Stony brown clay	75	0	21	0
Plastic clay	86	0	11	0
Gravel	102	0	16	0
Vein of rock	103	0	1	0
Red marl	136	0	33	0
Red marl, with veins of sand	161	0	25	0
Fine red rock	166	0	5	0
Red and grey marl	182	0	16	0
Red sandstone	192	0	10	0
Red marl	200	6	8	6
Red sandstone	205	0	4	6
Vein of red sand	206	0	1	0
Dark red rock	214	0	8	0
Red and grey marl	222	6	8	6
Fine red sandstone	235	0	12	6
Marly red sandstone	237	0	2	0
Fine red sandstone	250	0	13	0
Red and grey marl	257	0	7	0
Red sandstone	262	0	5	0
Close dark red sandstone	274	0	12	0
Grey marl	274	6	0	6
Close dark red sandstone	277	0	2	6
Grey marl	279	0	2	0
Grey sandstone	286	0	7	0
Grey marl	287	0	1	0
Grey sandstone	303	0	16	0
Grey marl	304	0	1	0
Grey sandstone	307	0	3	0

Trial Boring for Frodsham Gas and Water Co., in field 206 *in* 25-*inch map of Frodsham, Sheet* xxiv. 16, *made by Messrs. Timmins of Runcorn, diameter* $3\frac{1}{8}$ *ins. Communicated by* Mr. Henry Bancroft, C.E., *Manchester.*

Ft.	in.		Ft.	in.
6	0	Marsh clay	6	0
8	0	Marsh silt	2	0
10	0	Red marl (?boulder clay)	4	0
85	0	Fine red sandstone	75	0
93	0	Marl	8	0
99	0	Loamy sandstone	6	0
122	0	Fine red sandstone	23	0
129	0	Loamy red sandstone	7	0
140	0	Fine red sandstone	11	0

The yield of water at 122 feet was 1,200 gallons per hour, at 150 feet 1,600 gallons.

NOTTINGHAMSHIRE.

Information collected by Mr. TALBOT AVELINE, F.G.S., *in* 1878.

Boring at Chilwell, Trent Valley.

Ft.	in.		Ft.	in.
13	8	Alluvium gravel and sand	13	8
180	8	Red marl and white sandstone	167	0
430	8	Pebble beds	250	0
463	8	Soft sandstone	33	0
1,340	5	Coal-measures	876	9

Boring further down the Trent Valley, a little S.E. of Highfield House.

Ft.	in.		Ft.	in.
22	0	Alluvium	22	0
256	0	Bunter sandstone	234	0
303	5½	Coal-measures	47	5½
		First coal	?	

The boring was carried to the Deep Hard Coal at 610 feet from the surface.

Borings in the Trent Valley, near Long Eaton, made by Mr. GEO. HODSON, C.E., F.G.S., *Loughborough.*

Bore-hole No. 1. *Sawley,* 98 *feet above O.D.*

Ft.	in.		Ft.	in.
4	0	Surface soil	4	0
6	0	Sand	2	0
13	0	Coarse gravel	7	0
19	0	Sand	6	0
25	0	Very coarse gravel	6	0
31	0	Soft red Keuper marl, with bands of grey 'skerry'	6	0
35	0	Soft red marl, with gypsum	4	0
137	0	Red marl, with skerry and gypsum	102	0
140	0	Grey sandstone (skerry), marl partings	3	0
142	0	Red marl, thin sandstone bands	2	0
143	4	Very hard sandstone, 'skerry'	1	4
144	4	Soft marly sandstone	1	0
155	2	Very hard sandstone, traces of gypsum	10	10
164	2	Red marl, with skerry band	9	0

Boring No. 3. *Weston* (*Porter's 2nd field*) 120 *feet above Ordnance datum,* 6 *feet above the Trent.*

Ft.	in.		Ft.	in.
14	0	Gravel and sand	14	0
22	0	Red marl	8	0
33	0	Sandstone	11	0
34	0	Blue flakes (=marl)	1	0
36	0	Red marl	2	0
39	0	Sandstone	3	0
53	0	Coarser sandstone	14	0
74	9	Finer sandstone	21	9
77	9	Sandy marl	3	0
87	9	Sandstone	10	0
152	6	Red marls and skerry beds	64	9

West of Castle Donington. No. 10 Boring, at Stanton, in the Millstone Grit series, 136 feet above O. D.

Ft.	in.		Ft.	in.
5	0	Surface soil (sandy)	5	0
10	0	Hard whinstone nodules	5	0
14	6	Red rough sandstone	4	6
17	6	Dark red sandstone	3	0
25	6	Yellow sandstone	8	0
59	6	Dark yellow sandstone	34	0
68	6	Dark soft shale	9	0
71	6	Shale with sandy bands	3	0
112	0	Shale	40	6
113	7	Very hard yellow sandstone	1	7
117	3	Softer sandstone	3	8
118	1	Extra hard sandstone	0	10
120	4	Rather softer sandstone	2	3

Yorkshire.

Information from Mr. Geo. Hodson, C.E., F.G.S. *Snaith Waterworks boring, completed June* 1890.

Ft.		Ft.
930	New red sandstone, base probably Permian	930
950	Magnesian limestone	20

Boring on Lackenby Foreshore, East of Middlesbrough. Messrs. T. C. Hutchinson & Co. Made by Messrs. Mather & Platt, *of Salford Iron Works.*

Boring commenced at high-water mark in July 1889, carried out with the 'American rig' or chopping process.

Ft.	in.		Ft.	in.
13	0	Clay and gravel	13	0
24	8	Hard red clay, little gypsum	11	8
87	0	Red marl, thin rock	62	4
246	8	Red marl and blue bands	159	8
255	0	Hard band	8	4
343	0	Blue and red marl	88	0
373	0	Dark red marl and blue stone	30	0
380	0	Hard blue stone	7	0
597	0	Red marl	217	0
1,195	0	Red sandstone	598	0
1,272	0	Red marl	77	0
1,643	0	Red marl and sandstone bed	371	0
1,663	0	Hard white rock, *anhydrite*	20	0
1,672	0	Honeycomb rock, *anhydrite*	9	0
1,685	0	Salt and marl mixed, *anhydrite*	13	0
1,804	0	Clear salt-rock	119	0
1.806	0	White rock	2	0

In abstract this section gives:—

	Ft.	in.
Upper gypsum marls	597	0
Red sandstone	598	0
Lower gypsum marls	448	0
Anhydrite beds	42	0
Rock salt	119	0
Anhydrite	2	0

The red sandstone does not appear to have been interbedded with the usual marl bands, but this may be due to the method of boring; in all cases a piece should be cut out of the boring-chisel, to bring large pieces of the rock for examination.

WARWICKSHIRE.

The Coventry Corporation Waterworks consist of a series of bore-holes, discharging into a tank at Spon End, by natural artesian pressure. From the tank water is pumped to a service-reservoir above the city. No water is pumped from the ground, and the water therefore maintains its purity.

The site of the No. 1 bore-hole, and subsequent operations, have been the care of Mr. Hawksley, C.E., up to the last bore-hole, which was jointly recommended by Mr. Hawksley and your reporter.

No. 1 was completed in November 1855, and was carried from the bottom of the storage tank, at a point S. 17° W. from the centre, near the edge. For the section I am indebted to Mr. Purnell, C.E., the city engineer. The bottom of the tank is 21 feet 9 inches below the surface of the ground, when No. 2 bore-hole, or rather the well above it, commences, the upper crust of which is taken as the surface in Nos. 1 and 2 bore-hole sections. The tank is 16 feet in depth, and generally contains 13 feet of water.

No. 1 Bore-hole.

Ft.	in.		Ft.	in.
21	9	To bottom of tank	21	9
81	0	Red sandstone	59	3
136	0	Very compact red marl	55	0
143	0	Red sandstone	7	0
176	0	Red marl	33	0
177	0	White sandstone	1	0
190	0	Red sandstone	13	0
195	0	Red marl	5	0

No. 2 boring, completed in September 1860, carried from bottom of well, 24 feet 9 inches deep, about 20 feet outside the limit of the tank, in S. 30° E. direction, but the water flows into it by natural pressure.

Section of No. 2.

Ft.	in.		Ft.	in.
24	9	Details unknown	24	9
32	9	Red marl	8	0
34	9	Sandstone	2	0
40	9	Red marl	6	0
62	0	Sandstone	21	3
71	9	Red marl	9	9
84	9	Sandstone	13	0
86	9	Red marl	2	0
100	0	Very hard sandstone	13	3
114	0	Red marl	14	0
115	0	Very hard 'cank rock'	1	0
119	0	Red marl	4	0
124	0	Sandstone	5	0
125	0	Red marl	1	0
127	0	Sandstone	2	0
128	9	Red marl	1	9
130	0	Sandstone	1	3
131	0	Red marl	1	0
138	0	Sandstone	7	0
170	0	Red marl	32	0
190	0	Very hard sandstone, pebbles	20	0

Ft.	in.		Ft.	in.
191	0	Red marl	1	0
200	0	Very hard sandstone	9	0
203	0	Red marl	3	0
210	0	Red sandstone	7	0
233	0	Yellow sandstone (water)	23	0
234	0	Red marl	1	0
236	0	Sandstone	2	0
237	0	Red marl	1	0
245	0	Sandstone, water pebbles	8	0
250	0	Red marl	5	0
278	0	Very hard sandstone (water)	28	0
282	0	Red marl	4	0
300	0	Sandstone	18	0

No. 5. Boring details by Mr. Councillor ANDREWS, *Coventry. Bored in* 1874.

Surface level, 16 feet above bottom of the tank, sunk within the tank, near the margin, at a point N. 30° W. from the centre.

Ft.	in.		Ft.	in.
65	0	Marls	65	0
72	0	Sandstone	7	0
79	0	Marls	7	0
100	0	Sandstone	21	0
108	0	Marls	8	0
134	0	Sandstone	26	0
140	0	Marls	6	0
160	0	Sandstone	20	0
173	0	Marls	13	0
176	0	Sandstone	3	0
180	0	Marls	4	0
185	0	Sandstone	1	0
188	0	Marls	3	0
191	0	Sandstone	3	0
193	0	Marls	2	0
200	0	Sandstone	7	0
230	0	Marls	30	0
251	0	Sandstone	21	0
253	0	Marls	2	0
263	0	Sandstone	10	0
266	0	Marls	3	0
273	0	Sandstone	7	0
295	0	Yellow sandstone	22	0
296	0	Marls	1	6
306	0	Sandstone	9	6
308	6	Marls	2	6
336	0	Sandstone	27	6
350	0	Marls	14	0
368	0	Sandstone	18	0
378	0	Marls	10	0
426	0	White sandstone, possibly Coal-measures	48	0

Borings, 75 feet in depth, all carried from points within the tank, near its margin, due east from the centre, and N. 37° W.

Before No. 5 was bored the total supply was 600,000 gallons per day; the new work brought it up to 760,000 gallons a day.

The new well is 199 feet to the N.N.W. of the tank, and is 50 feet in depth; the water, rising in it by artesian pressure, is delivered into an iron pipe of 2 feet external diameter (18 inches interior), placed in the well at a depth of 22 feet from the surface, the latter being 267·30 feet above datum. At the bottom of the well a 30-inch iron pipe, 12 feet long, is placed in the centre, 6 feet being above the bottom of the well, and 6 feet below it; in this is placed the 24-inch lining tube, which rises to 10 feet above the bottom of the well. The top of the 24-inch lining tube is 227 feet above datum, the sole of the delivery pipes, which are sunk about 20 feet below the surface of the ground, being 245 feet, the sole of the pipe at the outlet end in the tank being the same. The top of the tank wall is 261·50 feet. The tank is circular, and 100 feet in diameter.

Section of Strata at Spon End Waterworks new boring.

The contractors, Messrs. Timmins, of Runcorn, are responsible for the measurement of the beds. The description of the strata is by Mr. Councillor W. Andrews, of Coventry.

All the beds are red unless otherwise stated. Mottled means red and white.

Well:—

Feet.		Feet.
1	Soil	1
9	Mottled marl	8
9½	Hard mottled shale	0½
17	Mottled marl	7½
18	Hard white sandstone with mica sparkles	1
20	Hard red marl	2
21¼	Hard brown sandstone with crystalline lustre	1¼
26	Softer red marl	4¾
	Hard mottled sandstone	0½
28	,, ,, marl	1½
29	,, ,, sandstone	1
30	Hard red sandy marl	1
½	Hard white or mottled sandstone	1½
34	Hard red marl	2½
35½	Hard grey sandstone	1½
37	Hard white ,,	1½
41	Very hard red marl	4
48	Coarse hard red sandstone	7
50	Soft red sandstone, bottom of well, dip south 1 in 18	2

Bore-hole:—

72	Hard pebbly conglomerate	22
77	Softer ,, ,,	5
80	Hard buff-coloured sandstone	3
81	Soft mottled sandstone	1
83	Hard pebbly conglomerate	2
86	Red marl	3
91	Red sandstone	5
112	Hard red marl	21
125	Pale red sandstone	13
131	Mottled marl	6
135	Red sandstone, with water	4
137	Grey sandstone, full of black specks, water	2
164	Red marl	27
168	Red sandstone	4
182	Hard conglomerate	14
198	Red sandstone, with water	16
199	Red marl	1
202	Soft red sandstone	3
211	Red marl	9
219	Dark red sandstone	8

Feet		Feet
239	Coarse red sandstone grit	20
246	Hard conglomerate	7
247	Yellow sandstone	1
248½	Red and yellow marls	1½
250	Hard conglomerate	1½
251	Red marl	1
254	Red sandstone	3
262	Hard conglomerate	8
266	Red sandstone	4
268	Hard red marl	2
272	Red sandstone	4
274	Red marl	2
280	Very hard red sandstone	6
290	Red sandy marl	10
293	Red marl	3
304	Red sandstone	11
306	Hard red marl	2
310	Red sandstone	4
321	Reddish-yellow sandstone, water	11
332	Red sandy marl, with white specks	11
334	Hard red marl	2
336	Hard red conglomerate	3
342	Hard brown and white mottled sandstone	6
400	Red marl with 'fish eyes'	58
402	Mottled marl	2
405	White sandstone	3
417	Red ,,	12
418	Hard grey sandstone	1
418½	Mottled marl	0½
423½	Reddish-grey sandstone	5
426	White sandstone	2½
432	Red marl	6
434	Hard red sandy marl	2
454	Hard conglomerate	20
457	Hard coarse white grit	3
460	Hard red sandy marl	3
472	Greyish-red sandstone	12
486	Red sandstone	14
565	Red marl with 'fish eyes'	79
575	Red sandstone	10

The saline water was tapped in the lowest bed of sandstone, under the 79 feet of marl.

Size of bore-hole 24-inch, 21-inch, and 18-inch.

Test Yields of Water from Boring at the Coventry Water Works.

	Galls. per Hour.	
1886, June 26	1,466	Yield of well before boring commenced; 8,400 gallons last test.
July 13	2,497	
,, 21	5,600	
Aug. 14	7,472	
Oct. 15	10,323	Bore-hole 115 feet deep.
1887, Mar. 6	14,880	Bore-hole 216 feet deep.
,, 30	15,000	Bore-hole 264 feet deep.
Nov. 20	7,260	(Natural flow into the filter beds.) Bore hole, 400 feet deep.
1888, Jan. 2	17,320	
,, 21	20,000	(522½ feet deep.) At level of bottom of 100 feet tank.
,, ,,	15,376	Rising from 6 feet to 8 feet in tank.

Above tests were taken at different levels, so are not very suitable for comparison. The last 175 feet of the boring appears to have added nothing to the supply.

The boring was carried to a depth of 575 feet, and yielded water of good quality, but in the last 10 feet, under the 79 feet of marl, an alkaline water was met with, which, when first tapped, was found by Mr. A. Timmins, A.I.C.E., F.G.S., to contain—

	Grains.
Total solids per gallon	561·05
Sulphuric anhydride	239·91
Lime	37·80
Magnesium	12·09
Combined chlorine	66·10

The following analysis gives further details of the alkaline water after it had been flowing a short time:—

Results of the Analysis of a sample of Water received from Coventry at the laboratory of the London Hospital Medical College, Whitechapel, London, on March 16, 1888, *and contained in a Winchester quart bottle, duly sealed and secured. By* Dr. Meymott Tidy.

(The results are stated in grains per imperial gallon of 70,000 grains, the organic carbon and nitrogen being stated in parts per 100,000.)

Total Solid Matter	Ammonia	Nitrogen in Nitrates and Nitrites = Nitric Acid	Oxygen required to Oxidise the Organic Matter	Organic Carbon	Organic Nitrogen	Lime (CaO)
Grains 557·80	Grains 0·070	Grains 0·083 N in 0·373 NHO_3	Grains 0	Part per 100,000 0·041	0·036	Grains 43·98

Magnesia (MgO)	Sulphuric Anhydride (SO_3)	Chlorine = Common Salt	Hardness Before Boiling	Hardness After Boiling	—
Grains 13·49	Grains 260·0	Grains 82·368 = 134·99	106°·3	25°·4	Silica, 1·04

Possible Composition.

Carbonates of lime and magnesia	27·0
Sulphates of lime and magnesia	90·5
Alkaline sulphates	300·0
Silica	1·0
Organic matter	0·0
Nitrate of magnesia	0·5
Chloride of sodium	134·9
	553·9
Actually found	557·8

Through the kindness of Mr. F. G. Meacham, M.E., of the Hampstead Colliery, Great Barr, near Birmingham, the specimens preserved from their sinking-pit have been examined by your reporter. Of the section passed through, 150 feet of white sandstone overlie Permian red sandstone marls and conglomerate like those of Spon End, which ter-

(Grains per Gallon.)

—	Marston (Cheshire) Brine	Stafford Corporation; Enson Moor Boring	Rose Bridge Colliery, Wigan	Dukinfield Colliery, Cheshire	Moira Main Colliery, Leicester	St. Clement's Well, Oxford	Royal Old Well, Cheltenham	Bath Great Well, Leamington	Purton Spring, Swindon	King's Bath at Bath	Hampstead Colliery, Great Barr	Coventry Water Works, New Boring
Chloride of sodium	17655·40	681·50	2606·021	3150·00	3700·50	748·30	590·33	476·96	34·30	12·64	2261·57	134·99
Chloride of magnesium	—	—	306·298	182·00	16·00	27·23	8·00	115·44	—	14·58	138·43	—
Chloride of potassium	—	—	602·061	—	Trace	—	—	—	—	—	0·3	—
Chloride of calcium	—	—	—	259·00	851·20	—	—	78·00	—	—	219·89	—
Sulphate of sodium	102·20	—	102·026	—	—	357·63	94·94	68·72	114·15	23·87	—	} 260 00
Sulphate of potassium	Trace	—	82·064	—	—	—	—	—	Trace	Trace	—	
Sulphate of magnesium	—	—	—	—	—	—	—	—	77·20	—	—	13·49 (including other salts)
Sulphate of calcium	—	—	106·612	—	—	135·37	—	190·00	83·87	80·05	174·93	43·98 (including carbonate)
Carbonate of sodium	25·20	—	—	—	—	—	—	—	23·88	—	—	—
Carbonate of magnesium	74·90	—	33·064	—	—	—	6·80	—	—	0·33	—	—
Carbonate of calcium	Trace	—	91·021	—	—	7·63	17·06	—	—	8·82	41·63	—
Iodide, or bromide of sodium	7·70	—	36·024	—	8·00	Trace	3·50	Trace	0·1	—	—	—
Iron	—	—	Trace	—	Trace	Trace	—	Trace	0·28	1·07	2·18 carbonate	—
Silica	—	—	94·021	—	—	1·26	2·75	Trace	1·28	2·18	0·35	—
Organic matter	—	—	—	—	—	0·10	18·39	—	8 75	—	0·45	—
	—	—	4088·800	3591·00	4575·70	1277·52	741·77	929·12	348·87	144·34	2845·03	557·00

minate at 627 feet from the surface and overlie purple coal-measure with *spirorbis* limestone, to a depth of 1,470 feet, when a conglomerate occurs. At 1,668 feet occurs the first seam of coal, and the Staffordshire thick coal at 1,850 feet (615 to 625 yards). 'Fish eyed' spots commence at 597 feet from the surface, and continue to 729 feet, after which they are much smaller, and continue to 1,020 feet. A salt spring occurred at 1,000 feet, and good water in the sandstone above. The saline spring was analysed by Dr. Knipe, of Handsworth.

	Grains per Gallon.
Water tapped by the L. N. W. Railway at Northampton at a depth of 650 feet contained chloride of sodium, carbonate of soda, and sulphates of magnesia and lime	—
Water tapped by Northampton Water Company at Kettering Road yielded 200,000 gallons per day of saline water, from crystalline conglomerates and sandstone, lying between the lias, and carboniferous dolomitic limestone with fossils	1200·00
At Gayton, 2 miles N.W. of Blisworth Station, a boring 994 feet deep proved saline waters below the lias	1500·00
At Dallam Lane Forge, Warrington, a boring in the pebble beds gave saline water, increasing in salts with the depth	4500·00

Well Section at the Atherstone Water Works, Birchley Heath. Supplied by MR. BALDWIN LATHAM, *M.Inst.C.E.*

Mouth of well about 484 feet above Ordnance datum.

	Ft.
Red marl	10
Soft red sandstone	2
Hard red sandstone	16
Marl interstratified with hard bands of red sandstone	11
Hard red and grey sandstone	10
Red sandstone	10
Very hard red rock	6
Hard grey and red rock	7
Total	75

Samples of Rock at different depths.

At	38 ft.	absorbing capacity was	10·1 ;	specific gravity,	2·66
"	55 "	" "	10·6	" "	2·66
"	58 "	" "	8·86	" "	2·68
"	65 "	" "	8·02	" "	2·69

East Warwickshire Water Works. Section of Well at Stockingford. Supplied by MR. JOHN ANSTIE, *M.Inst.C.E.*

Character of Strata	Thickness Ft.	in.	Total Depth Ft.	in.	Remarks
Strong brown clay	67	0	67	0	
Light blue rock	3	8	70	8	
Marl, with balls of red rock .	97	10	167	6	
Strong marl.	15	6	182	0	
Red rock	1	6	—		
Dark grey rock	2	0	—		
Red marl	4	0	—		

Character of Strata	Thickness Ft.	Thickness in.	Total Depth Ft.	Total Depth in.	Remarks
Strong marl, mingled with red rock	3	0	—		
Hard red rock	2	0	—		
Strong marl, with balls of red rock	2	9	—		
Hard red sandstone (a little water)	1	9	—		
Marl	0	6	—		
Red rock	2	10	202	4	
Marl, mingled with light rock .	35	8	238	0	
Light rock	1	6	239	6	
Sandstone rock	8	9	248	3	
Peldon (with water) . . .	4	0	252	3	
Sandstone rock	8	9	261	0	Well sunk to this depth yielded 35,000 galls. daily.
Fine light rock, very strong .	6	6	267	6	
Red rocky marl	6	0	273	6	
Light soft marl	2	6	276	0	
Red marl, with balls of white rock	29	6	305	6	
Light red rock, very hard . .	24	6	330	0	Well sunk to this depth and headings driven under rock increased yield to 150,000 galls. daily.
Marl	6	0	336	0	Floor of well.
Hard red rock	2	0	338	0	Bore-hole.
Marl	30	0	368	0	
Hard light rock (with water) .	6	0	374	0	
White rock, very strong . .	9	0	383	0	
Strong marl	1	9	384	9	
Red rock	2	0	386	9	
Strong rocky marl . . .	4	9	391	6	
Marl	2	6	394	0	

If pumping is stopped for 48 hours the water rises about 100 feet in the well; above that the rise is very slow. Ordnance level of top of well, 474·0 feet.

Final Report of the Committee, consisting of Mr. J. W. Davis, Mr. W. Cash, Dr. H. Hicks, Mr. G. W. Lamplugh, Mr. C. Reid, Dr. H. Woodward, *and* Mr. T. Boynton, *appointed for the purpose of investigating an Ancient Sea-beach near Bridlington Quay.* (*Drawn up by* G. W. Lamplugh, *Secretary.*)

The abundant material obtained during the excavation of the Sewerby Cliff-beds two years ago has, at the cost of much time and trouble, been thoroughly dealt with. All the bones have undergone a hardening process by immersion in weak glue, and the most promising specimens have been pieced together, being thus, in most cases, rendered determinable.

The results, however, have been somewhat disappointing, as the bones have proved to belong in nearly every case to the species whose presence was already known.

Nevertheless, several doubtful points have been cleared up and a good foundation laid for further investigation.

The following list embodies the emendations, and represents the sum of our present knowledge of the fauna. The Committee desires to express its great obligation to Mr. E. T. Newton for his kindness in undertaking the examination of the specimens.

Fossils from the Sewerby Cliff-beds	Old Beach	Rain-wash	Blown Sand	Remarks
Elephas antiquus, Falc.	*	—	*	Several molars from the old beach and three from the blown sand; also some broken limb-bones, &c., in the old beach.
Rhinoceros leptorhinus, Cuv.	*	—	?	Several molars, portions of a lower jaw and other bones.
Hippopotamus amphibius, Linn.	*	—	—	One molar and a badly-preserved tusk.
Cervus (? *megaceros*, Hart)	—	—	—	*Fide* 'Geol. Survey Mem.,' Holderness, p. 49
Bison, sp.	*	*	*	Many bones and a few teeth: some of the bones may possibly belong to *Bos primigenius*.
Hyæna crocuta, var. *spelæa* ? Goldf.	*	—	*	An ulna; also indicated by gnawing on many of the bones.
Arvicola amphibius, Linn.	—	*	—	Lower front molar and two incisors.
Birds	*	*	—	Three or four limb-bones.
Gadus morrhua, Linn.	*	—	—	Vertebræ and bones of the head.
LAND MOLLUSCA.				
Helix hispida, Linn.	—	*	—	All species still living in this country.
Helix pulchella, Müll.	—	*	—	
Pupa marginata, Drap.	—	*	—	
Zua subcylindrica, Linn. (*Z. lubrica*, Müll.)	—	*	—	
MARINE MOLLUSCA.				
Purpura lapillus, L.	*	—	—	All species which abound in the recent beach, except *Ostrea*, which is not now found living in Bridlington Bay. *Pholas* and *Saxicava* are indicated by their empty borings.
Littorina littorea, L.	*	—	—	
Ostrea edulis, L.	*	—	—	
Mytilus edulis, L.	*	—	—	
Pholas	*	—	—	
Saxicava	*	—	—	

The stratigraphical relation of the deposits was fully discussed in our previous report,[1] and on this point no further information has been gained excepting that the identification of the boulder-clay overlapping the Cliff-beds as the Basement Clay has been confirmed by the discovery of a characteristic transported fragment of fossiliferous clay and sand ('Bridlington Crag') in the boulder-clay overlying the chalk in the cliff at South Sea Landing, two miles east of the Buried Cliff.[2]

The fauna, as above recorded, still unfortunately remains without any distinctive species to show whether the beds may date back to the commencement of the glacial period, or whether, as has been suggested, they are really interglacial.[3] The opinion of the writer, as expressed in a

[1] *Rep. Brit. Assoc.* Bath, 1888, p. 328.

[2] See description of this section in *Geol. Mag.* Dec. III. vol. vii. p. 61 (Feb. 1890).

[3] *Geol. Survey Mem.* 'Holderness,' p. 48.

recent paper,[1] is that the Basement Clay was the first boulder-clay to be formed in the district, and that as the Sewerby Cliff-beds are distinctly older than this clay, they must have pre-dated any actual glaciation of the east coast. A systematic investigation is now being made into the details of the glacial beds of the whole of Flamborough Head which it is hoped may yield further evidence on this question.

The erratic pebbles which were obtained from the Old Beach have been examined and counted, with the result shown in the following table:—

Pebbles in the Old Beach.

	Per Cent.
Carbonaceous Shale; origin uncertain . . . . . about	10
Sandstones; in most cases not determinable, but many are *not* Secondary rocks	25
Quartzites	20
Palæozoic conglomerates	3
Vein-quartz pebbles	4
Basaltic rocks	17
Porphyritic felsites and other igneous rocks	13
Granites	2
Oolitic limestones	4
Black and yellow flint (not local)	2
	100

Most of these pebbles were well rounded; but a few were subangular, as if they had not been long exposed to the pounding of the beach. If the above table be compared with the lists of boulders from the boulder-clays compiled by the writer at various places on the Yorkshire coast [2] some important differences will be observed.

Perhaps the most striking of these differences is that in this table there are *no* pebbles from the Carboniferous Limestone, a rock which abounds everywhere in the overlying glacial series. The quartzites and igneous rocks, vaguely classed as 'porphyritic felsites,' are also in much higher proportion here than in the boulder-clays. Taken as a whole, it may be said that these pebbles have travelled further than a similar collection taken at random from the East Yorkshire glacial-beds.

We do not propose to proceed further with this investigation at present, as the difficulties of the excavation are such, owing to the great depth of the loose sand, that it would be necessary to undertake much costly and unprofitable labour to render the work free from danger. Meanwhile the steady encroachment of the sea is slowly preparing another slice of the deposits for easy exploration in the future.

We are greatly indebted to the Lord of the Manor for his courteous permission to carry out the excavation, and desire to record our thanks to him.

The collection of fossils has been deposited in the Museum of Practical Geology, 28 Jermyn Street, London.

[1] *Proc. Yorksh. Geol. and Pol. Soc.* vol. xi. pt. ii. (1889), p. 275.

[2] See papers in *Proc. Yorksh. Geol. and Pol. Soc.* vol. ix. pt. iii. p. 339; vol. xi. pt. ii. p. 231; and also abstract elsewhere in this vol., Proceedings of Section C.

Report of the Committee, consisting of Dr. H. Woodward, Mr. G. R. Vine (*Secretary*), Drs. P. M. Duncan, H. C. Sorby, *and* Mr. C. E. De Rance, *appointed to prepare a report on the Cretaceous Polyzoa.* (*Drawn up by* Mr. G. R. Vine.)

The Polyzoa of the Cretaceous epoch have been partially dealt with in two of my previous reports;[1] owing to recent researches I am compelled to return to the subject. In this supplementary report, however, I shall confine my attention to the study of the stratigraphical distribution of British Cretaceous Polyzoa only, and that chiefly of species found in the lower beds of the Upper Cretaceous series, and in the Neocomian rocks below.

Recently these lower beds of the Upper Cretaceous series have occupied a good deal of special attention from the members of the Geological Survey and others. The various zones of the Chalk have been carefully studied in several localities, and comparative lists of fossils published; but, as I find no mention of Polyzoan remains in any of these lists, it may not be deemed out of place if I endeavour to supply this deficiency in the present report.

In the second (or Palæontological) part of Phillips's 'Manual of Geology,' Mr. Etheridge[2] has given an elaborate analysis of the distribution of Cretaceous fossils in our British rocks. In the division of that list devoted to the Polyzoa, the author enumerates, under 59 generic names, altogether about 114 species as having been either catalogued or described from the whole of the Cretaceous series. It will be convenient, therefore, to take Mr. Etheridge's list as the basis of this report, in order to draw the attention of the working palæontologist to the value of Polyzoa in dealing with, or characterising differences in, the various British Cretaceous beds. The evidence as regards the zones, I admit, is not complete; and for the simple reason that only a very few students, as yet, have entrusted me, for examination, with fossils from special zones on which polyzoan incrustations are found. All the evidence, however, that I am now able to offer, is the result of the careful study of over twelve hundred fossils derived from different horizons of the Chalk, both Upper and Lower,[3] and from British Neocomian, or so-called Neocomian, beds below.

The 114 Cretaceous species of Polyzoa are distributed as follow:—

—	Genera	Species
Upper Chalk	38	61
Lower Chalk	6	6
Chalk Marl	1	1
Cenomanian, or Upper Greensand	15	23
Albian, or Gault	3	4
Neocomian, or Lower Greensand	21	34

As nearly the whole of the generic names which are adopted by Mr.

[1] Fourth (Brit. Assoc.) Report on Fossil Polyzoa. 1883. Fifth Report on Fossil Polyzoa. 1884.

[2] New edition, 1885, pp. 589 and 590.

[3] The evidence from the Middle beds is incomplete.

Etheridge were proposed by M. d'Orbigny for his elaborate classification of the Cretaceous Bryozoa of France,[1] it may be well to preface the following analysis with the latest arrangement of the Cyclostomata. In 1887 Dr. Pergens, of Belgium, spent several months in the study of the d'Orbigny collection of Bryozoa, now preserved in the Natural History Museum of Paris. Since d'Orbigny completed his work some of the examples have become useless as types; that is to say, some of the labelled examples do not correspond with the description and figures of his text and atlas. The names of the doubtful species, however, are preserved by Dr. Pergens in a separate list; whilst others are redescribed and re-illustrated; and in a few cases new names are given to examples which were only partially described by the author. Only the first part of the revision, the Cyclostomata, is published as yet;[2] but the following synopsis of the family and generic arrangement adopted by Dr. Pergens will enable the student to appreciate, more fully than he otherwise would, the value of d'Orbigny's labours on the Polyzoa, especially so when it is stated that of the Cyclostomata alone Dr. Pergens catalogues, as good species, about 253; besides which there are at least 75 doubtful forms also catalogued.

CYCLOSTOMATA (pars), Busk.

Division (A.), SOLENOPORINA, Marsson.

I. Family CRISIIDÆ.—Genus: *Unicrisia*, d'Orb.

II. Family DIASTOPORIDÆ.—Genera: *Stomatopora*, Bronn. *Diastopora*, Lamx. *Cellulipora*, d'Orb. *Discosparsa*, d'Orb. *Ditaxia*, Hagenow.

III. Family IDMONEIDÆ.—Genera: *Reptotubigera*, d'Orb. *Semiclausa*, d'Orb. *Reptoclausa*, d'Orb. *Idmonea*, Lamx. *Filisparsa*, d'Orb. *Filicavea*, d'Orb. *Filicrisina*, d'Orb. *Hornera*, Lamx. *Spiroclausa*, d'Orb. *Reticulipora*, d'Orb. *Retecava*, d'Orb. *Bicrisina*, d'Orb.

IV. Family ENTALOPHORIDÆ.—Genera: *Entalophora*, Lamx. *Spiropora*, Lamx. *Peripora*, d'Orb. *Bidiastopora*, d'Orb. *Sulcocava*, d'Orb. *Mesenteripora*, Blainv. *Heteropora*, Blainv.

V. Family FASCIGERIDÆ.—Genera: *Filifascigera*, *Reptofascigera*, *Semitubigera*, *Multifascigera*, *Semifascipora*, *Discofascigera*, *Fasciculipora*, *Osculipora*, *Cyrtopora*, *Frondipora*, *Fascipora*, *Plethopora*.—All d'Orbigny.

VI. Family LICHENOPORIDÆ.—Genera: *Conotubigera*, d'Orb. *Apsendesia*, Lamx. *Multicavea*, d'Orb. *Lichenopora*, Defr. *Multicrisina*, d'Orb. *Stellocavea*, d'Orb.

VII. Family CYTISIDÆ.—Genera: *Discocytis*, d'Orb. *Truncatula*, Hag. *Supercytis*, d'Orb. *Semicytis*, d'Orb. *Cytis*, d'Orb. *Unicytis*, d'Orb.

VIII. Family CERIOPORIDÆ.—Genera: *Reptomulticava*, d'Orb. *Ceriopora*, Goldf. *Echinocava*, d'Orb. *Clavicava*, d'Orb.

[1] *Paléont. Franç.* tome v.; *Terr. Crét.* 1850–52.

[2] 'Revision des Bryoz. du Crétacé, figurés par d'Orbigny:' Dr. Ed. Pergens, *Bull. Soc. Belge, Géol.* &c. tome ii. pp. 305–400. 1889.

Division (B.), CEINA.

IX. Family CEIDÆ.—Genera: *Semicea*, d'Orb. *Discocea*, Perg. *Filicea*, d'Orb. *Cea*, d'Orb.

Division (C.), MELICERTITINA.

X. Family MELICERTITIDÆ.—Genera: *Semielea*, d'Orb. *Clausimultelea*, d'Orb. *Melicertites*, Röm. *Elea*, d'Orb. (*Retelea* ?, d'Orb.)

At first sight this arrangement of genera may appear to be somewhat artificial; but the family grouping seems to me based on well-marked structural, rather than upon mere superficial characters. In the Cyclostomata generally there is less to build systematic arrangement upon than in the Cheilostomata; and what little there is has been well investigated by Mr. A. W. Waters, as indicated in his Australian papers. There are, however, two new divisions (the CEINA and MELICERTITINA) introduced into Dr. Pergens' classification, under which some very anomalous and hitherto very troublesome species are placed. Of the 'CEINA' group, as Dr. Pergens remarks, only one living representative exists—*Cinctopora elegans*, Hutton, var. *areolata*.[1] At present, however, I know of no living representative of the MELICERTITIDÆ.

Before leaving this part of my subject, it may be well to give a list of Cretaceous Polyzoa referred to by Mr. A. W. Waters in his Australian papers; because, if Mr. Waters is correct in his identifications, these Australian fossils must be regarded as the remnants of a once wide-spread Cretaceous fauna, some few members of which may still be living. There is, I must admit, a great difficulty in the way of accepting the views of Mr. Waters on this head. The Australian species indicated by him closely resemble, I am well aware, those figured by d'Orbigny in his 'Paléontologie Française,' but in all identifications of this kind there are, or may be, minute points of difference, which ought not to be overlooked, and which should influence the palæontologist in his decisions. In a letter to me Mr. Jesson remarks: 'The identity of the Australian and Cretaceous forms seems to me to go against the usefulness of Polyzoa in determining zones and the age of different deposits.' Possibly others may think so too, if the citation be allowed to pass unnoticed; and, therefore, the identifications are given on the authority of Mr. Waters.

CHEILOSTOMATA.

Vincularia argus,[2] d'Orb. Pal. Fr. p. 253, pl. 689, figs. 1–4.—*Membranipora argus*,[2] Waters.

Escharina confluens,[3] Reuss. Verst., Böhm. Kreid. *Membranipora confluens*, Reuss, in Geinitz's Elbthalgeb.; and Novák. *Membranipora pedunculata*, Hincks, Ann. Mag. Nat. Hist. (5), vol. vi. p. 377. —*M. confluens*,[3] Waters (p. 262).

Flustrellaria dentata,[3] d'Orb. Pal. Fr. p. 525, pl. 725, figs. 17–21. *Membranipora annulus*, Manzoni, Bryoz. Foss. Ital.; and Bryoz. Castrocaro.—*M. dentata*,[3] Waters (p. 263).

[1] See remarks on this species by Mr. Waters, 'Bryozoa from New Zealand,' *Q. J. Geol. Soc.* vol. xliii. p. 341.

[2] *Quart. Journ. Geol. Soc.* vol. xxxvii. (1881), p. 324.

[3] *Ibid.* vol. xxxviii. pp. 257-276

Cellepora hippocrepis,[1] Goldf. Petr. p. 26, pl. ix. fig. 3. *Membranipora bidens*, Busk; and Reuss. *Membranipora Rossellii*, Manzoni. —*Micropora hippocrepis*,[1] Waters (p. 264).

Cellepora marginopora,[1] Reuss, Foss. Polyp. Wien. Tert., p. 88, pl. x. fig. 23. *Reptescharellina prolifera*, Gabb and Horn (Cret. N. Amer.).—*Schizoporella marginopora*,[1] Waters (p. 274).

Of the Cyclostomatous [2] group we have the following:—

Tubigera disticha, d'Orb. Pal. Fr. p. 723, pl. 746, figs. 2–6. *Idmonea disticha*, Hag. Bryoz. Maastr. p. 30, pl. ii. fig. 8.—*Idmonea bifrons*, Waters (p. 685).

Ceriopora verticillata, Goldf. Petr. Germ. p. 36, pl. 11, fig. 1. *Spiropora antiqua*, d'Orb. Pal. Fr. p. 710, pl. 615, figs. 10–18, and pl. 745, figs. 15–19. *S. neocomiensis*, d'Orb. p. 708, pl. 784, figs. 1–2. *S. Calamus*, Gabb and Horn (N. American Cretaceous).—*Entalophora verticillata*, Waters (p. 685).

Entalophora raripora, d'Orb. Pal. Franç., Terr. Crét. p. 787, pl. 621, figs. 1–3.—*Entalophora raripora*, Waters (p. 686).

(See also Mr. Waters's long list of synonyms.)

Entalophora neocomiensis, d'Orb. Pal. Fr. p. 782, p. 616, figs. 15–18.—*Entalophora neocomiensis*, Waters (p. 686).

(See also list ot synonyms given by Mr. Waters.)

Apseudesia clypeata, Lamx. Haime, Bryoz. Form. Jur. p. 202, pl. 7, fig. 7. —*Discotubigera clypeata*, Waters (p. 690).

Pavotubigera flabellata, d'Orb. Pal. Fr. p. 767, pl. 752, figs. 4–8.—*Pavotubigera flabellata*, Waters (p. 691).

Supercytis digitata, d'Orb. Pal. Fr. p. 1061, pl. 798, figs. 6–9.—*Supercytis ? digitata*, Waters (p. 692).

Domopora cochloidea, d'Orb. Pal. Fr. p. 990, pl. 781, figs. 5–7.—*Lichenopora cochloidea*, Waters (p. 695).

Tecticavea boletiformis, d'Orb. (non Rss.), Pal. Fr. p. 991, pl. 781, figs. 8–12.—*Lichenopora boletiformis*, Waters (p. 695).

Bimulticavea variabilis, d'Orb. Pal. Fr. p. 983, pl. 779, figs. 9–13.—*Lichenopora variabilis*, Waters (p. 696).

Since my former reports on Fossil Polyzoa I have had placed in my hands, for study and description, some fine collections of Polyzoa from several Cretaceous horizons. Lists of Polyzoa, however, are rarely given by authors when tabulating the ordinary fauna of the different zones of the Chalk; and I am obliged to fall back on the general lists furnished by Professor Morris and Mr. Etheridge, when dealing with species outside my own special work.

In the first edition of his admirable 'Catalogue of British Fossils in 1845, Professor Morris dealt with Cretaceous and all other Polyzoa in accordance with the classificatory notions of that time; but in the 1854 edition he followed, to some extent, the leading of d'Orbigny. Little, in the way of lists, has been added to our knowledge of really new

[1] *Quart. Journ. Geol. Soc.* vol. xxxviii. pp. 257–276.
[2] *Ibid.* vol. xl. pp. 674–696.

Cretaceous Polyzoa since Professor Morris compiled his Catalogue. In the 'Catalogue of Cretaceous Fossils in the Museum of Practical Geology (1878)' we have some good lists, and characteristic fossils are preserved in the Museum from the following formations: Neocomian, or Lower Greensand; Blackdown beds; Upper Greensand; Lower and Upper Chalk; and there are still many undescribed Cretaceous Polyzoa in the cases and drawers of the Museum. In the Natural History branch of the British Museum, South Kensington, the Cretaceous Polyzoa are not fully arranged. There is a fine series here, but I am not able to give full particulars.

We owe to Professor J. Beete Jukes, as shown in 'The Student's Manual of Geology,' 1857, pp. 367, 368, and 495, indications of the stratigraphical distribution of the Cretaceous Polyzoa, epitomised from Pictet and d'Orbigny. It is useless in the present state of knowledge to reproduce these references, but it is well to direct attention to this early work of Jukes on the Palæontology of the Polyzoa.

I. Neocomian Polyzoa (Lower Greensand).

In the 'Catalogue of British Fossils' a certain number of Polyzoa are characterised as Lower Greensand species by Professor Morris. Most of the species so placed are derived from the Faringdon beds of Berkshire. Mr. Jukes, however, did not use these Polyzoa, catalogued by Morris, as true Lower Greensand species, and he remarks (p. 502): 'There are . . . . some still unsolved difficulties with respect to these [so-called Neocomian beds], inasmuch as in some Greensand deposits at Blackdown, in Devonshire, fossils of the Lower Greensand, Gault, and Upper Greensand seem to be curiously intermixed in such a way as to make the age of the deposit very doubtful. There are also some sand and gravels near Faringdon in Wiltshire [Berkshire], where Lower Greensand fossils are also mingled with others belonging to Upper Cretaceous rocks. Mr. Sharp believed these Faringdon gravel-beds to be of more recent date than the Chalk itself, though still belonging to the Cretaceous period. . . As the fossils from these and from some other localities are often quoted as Greensand fossils, they are calculated to confuse our classification.'

Professor Prestwich, in his 'Geology,' vol. ii., 1888, p. 271, refers the 'Faringdon Beds' to the Upper Neocomian, with the following Polyzoa: *Actinopora papyracea, Alecto Calypso, Pustulopora pseudospiralis, Ceriopora* (5 spp.), *Diastopora* (2 spp.), *Entalophora* (2 spp.), and *Reptomulticava* (2 spp.). Also in H. B. Woodward's 'Geology of England and Wales,' 2nd edition (1887), pp. 375, 376, the 'Faringdon Beds' hold their own as 'Lower Greensand.'

In the 'Catalogue of Cretaceous Fossils in the Museum of Practical Geology,'[1] most of the Lower Greensand Polyzoa have been derived from Faringdon, with but few exceptions, the chief of which are the following:—[2]

1. Ceriopora polymorpha, Goldfuss, Upware.
2. Echinocava Raulini, Michelin, Upware.
3. Entalophora ramosissima, d'Orb., Lockswell.
4. Radiopora bulbosa, d'Orb., Brickhill.
5. Siphodictyum gracile, Lonsdale, Atherfield.

[1] Ed. 1878, pp. 6–7. [2] I have omitted unnamed forms.

With the exception of No. 4, not one of these species is cited by Morris in his Catalogue; and I shall have to deal with the forms independently. The horizons of these fossils as given by foreign authors are the following:—

1. { Ceriopora polymorpha, Goldfuss.—Essen Greensand.
   Ceriopora polymorpha, Mich. = Reptomulticava Arduennensis, d'Orb.—Gault. }
2. Echinopora Raulini, Mich. (d'Orb.).—Gault.
3. Entalophora ramosissima, d'Orb.—Cenomanian.
4. Radiopora bulbosa, d'Orb.—Cenomanian.
5. Siphodictyum gracile, Lonsd. (local).—Neocomian.

If we now take the lists of Lower Greensand Polyzoa given by Professor Morris and Mr. Etheridge in the catalogues already referred to, we shall find that the Faringdon species may be conveniently redistributed (if the identifications of these authors be correct) into the several Cretaceous horizons which will be found mentioned further on. It will then be seen that very little reliance can be placed on the Faringdon Polyzoa as typical Lower Greensand species, and I think Professor Jukes was justified in rejecting the evidence as being stratigraphically incorrect.

List of Faringdon Polyzoa.[1]

1. Actinopora papyracea, d'Orb. Terr. Crét. pl. 643, figs. 12–14.
2. Ceriocava irregularis, d'Orb. Ib. pl. 788, figs. 15–16.
3. Ceriopora mamillosa, Röm. Kreidegeb. pl. 5, fig. 25.
4. " ramulosa, Mich. (*Ceriocava*, d'Orb.), Terr. Crét. pl. 788, figs. 11–12.
5. Diastopora? clavula, Morris (? Domopora clavula, d'Orb. pl. 647).
6. " gracilis ?, d'Orb. = *Flustra tubulosa*, Woodward, Geol. Norf. pl. 4, fig. 5.
7. " ramulosa, Mich. Icon. pl. 52, fig. 3.
8. " tuberosa, d'Orb. Terr. Crét. pl. 629, figs. 1–3.
9. Domopora tuberculata, d'Orb. Ib. pl. 648, figs. 1–4.
10. Entalophora cenomana, d'Orb. Ib. pl. 618, figs. 11–15.
11. " costata, d'Orb. Ib. pl. 621, figs. 19–22.
12. " Meudonensis, d'Orb. Ib. pl. 623, fig. 9.
13. " ramosissima, d'Orb. Ib. pl. 618, figs. 1–5.
14. " Sarthacensis, d'Orb. Ib. pl. 619, figs. 6–9.
15. { Heteropora tenera, Hag. Maestricht Bryozoa, pl. 5, fig. 14.
   = *Multicrescis Michelini*, d'Orb. Terr. } Crét. pl. 799, figs. 14–15.
16. Multicrescis mamillata, d'Orb. Ib. pl. 800, figs. 1–2.
17. " variabilis, d'Orb. Ib. pl. 800, figs. 3–7.
18. Proboscina marginata, d'Orb. Ib. pl. 759, fig. 4.
19. " subelegans, d'Orb. Ib. pl. 759, fig. 8.
20. Pustulopora pseudospiralis, Mich. (*Peripora*, d'Orb.), Ib. pl. 616, figs. 6–8.
21. Radiopora pustulosa, d'Orb. Ib. pl. 649, figs. 1–3.
22. Reptocea cenomana, d'Orb. Ib. pl. 788, figs. 1–3.
23. Reptomulticava collis, d'Orb. Ib. pl. 792, fig. 1.

[1] I have not classified or rearranged the species; but have given them as arranged in the *Catalogue of British Fossils*, and in the *Catalogue of the Museum of Practical Geology*.

24. Reptomulticava mamilla, d'Orb. Ib. pl. 793, figs. 3–4.
25. ,, micropora, d'Orb. Ib. pl. 791, figs. 10–12.
26. Reptotubigera elevata, d'Orb. Ib. pl. 760, figs. 1–3.
27. ,, marginata, d'Orb. Ib. pl. 750, figs. 19–21.
28. Zonopora undata, d'Orb. Ib. pl. 771, fig. 14.

The following additional Faringdon species are given from the 'Catalogue of Cretaceous Fossils in the Museum of Practical Geology.' I have only regarded named species:—

29. Actinopora elegans, Mich. (*Lopholepis*, Hag.), see d'Orb. Terr. Crét. p. 687.
30. Alecto reticulata, d'Orb. Ib. p. 841.
31. Proboscina ramosa, d'Orb. Ib. p. 851.
32. ,, ramosa ?, Michelin (*Diastopora ramosa* ?, Mich., see d'Orb. p. 851).
33. ,, cornucopiæ, d'Orb. Terr. Crét. p. 655.
34. Diastopora congesta, Reuss = *Reptomultisparsa congesta*, d'Orb. Ib. p. 878.
35. ,, papyracea, d'Orb. = *Berenicea papyracea*, d'Orb. Ib. p. 868.
36. Discocavea neocomiensis, d'Orb. Ib. p. 959.
37. Ceriopora avellana, Mich. Ib. p. 1034.
38. ,, cavernosa, Hag. Ib. p. 1034.
39. ,, polymorpha, Goldf. Ib. p. 1034.
40. Heteropora clavula, Mich. Ib. p. 1070.
41. Radioporia heteropora, d'Orb. Ib. p. 1035.
42. Semimulticrescis ramosa, d'Orb. Ib. p. 1078.

It will be evident from the above list that the Faringdon material is very rich as regards Polyzoa; but how far the forms may be regarded as a true Lower Greensand fauna may now be tested.

In his 'Prodromus of Palæontology,' and also in the appendix to the 'Cretaceous Bryozoa,' d'Orbigny has indicated by numbers (1 to 27),[1] the particular stages or horizons in the geological series of rocks in which Polyzoa had been found previously to his labours on the group. These studies form some of the most interesting considerations in his great work, for to a certain extent the Polyzoa, when carefully investigated, offer to the palæontologist many suggestions as to the probable age of the strata which come under his consideration. Every geological age has its peculiar group of Polyzoan forms, which may be utilised for the purpose of palæontology; but in this direction our labours at present are far behind those of some at least of the Continental and American workers. I shall therefore apply d'Orbigny's method in my endeavour to unravel the Polyzoan life-histories of the less-known Cretaceous faunas.

JURASSIC.—Stage 10. BAJOCIAN, d'Orb. (Jurassic). See Paléont. Franç. vol. v.; Terr. Crét. p. 894.

14.[2] Entalophora Sarthacensis, d'Orb. (*Clausa Sarthacensis*, d'Orb.), Ib. p. 894.

[1] See *Paléontologie Française*, tome v. p. 1082. 1850–52.

[2] The numbers in this column correspond with the numbers in the previous list; so the student will be able to detect the differences between the old and the new names. The arrangement of the Cretaceous Polyzoa is in accordance with Dr. Pergens' revision of d'Orbigny's 'Bryozoaires.'

CRETACEOUS.—Stage 17. NEOCOMIAN, d'Orb., Terr. Crét. p. 1089.

18. Proboscina marginata, d'Orb. (*Stomatopora marginata*, Pergens), Ib. p. 849.
6. Diastopora gracilis, Edw. (d'Orb.), Ib. p. 864.
40. Heteropora clavula, d'Orb. Ib. p. 1070.
41. Lichenopora heteropora, d'Orb. Ib. p. 993.
23. Reptomulticava collis, d'Orb. Ib. p. 1036.
25. Reptomulticava micropora, d'Orb. (*Radiopora heteropora*, Pergens), d'Orb. Ib. p. 1035.
36. Discocavea neocomiensis, d'Orb. (doubtful sp., Pergens), Ib. p. 759.

Stage 18. APTIAN, d'Orb. (Upper Neocomian, d'Orb.), Terr. Crét. p. 1089.

No record in British lists.

Stage 19. ALBIAN, d'Orb. (Gault).

16. Multicrescis mamillata, d'Orb. (species doubtful, Pergens), Terr. Crét. p. 1076.

Stage 20. CENOMANIAN, d'Orb.

30. Stomatopora granulata, Edw. Perg. Rev. des Bryoz. p. 329; pl. xi. fig. 2.
    (=*Stomatopora reticulata*, d'Orb. Terr. Crét. p. 841, pl. 630, fig. 1–4.)
19. Proboscina subelegans, d'Orb. (re-drawn and re-described by Pergens), Ib. p. 853.
32. Stomatopora Sarthacensis, Perg. (*Proboscina ramosa* in part, d'Orb.), Ib. p. 851.
13. Entalophora ramosissima, d'Orb. (same as No. 10, Pergens), Ib. p. 785.
10. Entalophora cenomana, d'Orb. (*Laterotubigera cenomana*, d'Orb.), Ib. p. 715.
20. Peripora pseudospiralis, Mich., d'Orb. Ib. p. 703.
17. Heteropora variabilis, d'Orb. Ib. p. 1077.
37. Ceriopora avellana, Mich., d'Orb. Ib. p. 1034.
22. Semicea cenomana, d'Orb. (*Reptocea cenomana*, d'Orb.), Ib. p. 1009.

Stage 21. TURONIAN, d'Orb.

2. Ceriopora irregularis, d'Orb. Terr. Crét. p. 1018.

Stage 22. SENONIAN, d'Orb.

33. Proboscina cornucopiæ, d'Orb. Terr. Crét. p. 855.
27. Reptotubigera marginata, d'Orb. Ib. p. 753.
26. „ (?) elevata, d'Orb. ('The example in the Paris Museum is a *Proboscina*,' Pergens), Ib. p. 755.
34. Diastopora congesta, d'Orb. (*Reptomultisparsa congesta*, d'Orb.), Ib. p. 878.

24. Reptomulticava mamilla, d'Orb. Ib. p. 1041.
28. Heteropora undata, d'Orb. (*Zonopora undata*, d'Orb.), Ib. p. 932.
1. Apsendesia papyracea, d'Orb. (*Unitubigera papyracea*, d'Orb.), Ib. p. 761.
3. Ceriopora mamillosa, Röm. (*Reptonodicava mamillosa*, d'Orb.), Ib. p. 1015.
12. Melicertites Meudonensis, d'Orb. (*Entalophora*, Morris), Ib. p. 622.

Stage 23. DANIAN, d'Orb.

15. Heteropora tenera, Hagenow, d'Orb. Terr. Crét. p. 1070.
29. Actinopora elegans? (*Lopholepis* sp., Hag.).
38. Ceriopora cavernosa, Hag., d'Orb. Terr. Crét. p. 1034.

By the above rearrangement it will be seen that the stratigraphical position of the Faringdon Polyzoa, if the species be identical with those of d'Orbigny's, will be as follows:—

JURASSIC FORMATION,	Stage	10—Bajocian, 1 species
CRETACEOUS FORMATION,	,,	17—Neocomian, 7 species.
,,	,,	18—Aptian, no record.
,,	,,	19—Albian (Gault), 1 species
,,	,,	20—Cenomanian, 9 species.
,,	,,	21—Turonian, 1 species.
,,	,,	22—Senonian, 9 species.
,,	,,	23—Danian, 3 species.

D'Orbigny divides the 'Bryozoaires' into two groups—CELLULINÉS (*Cheilostomata*, Busk), and CENTRIFUGINÉS (*Cyclostomata*, Busk); and he brings out the remarkable fact that, while the Polyzoa of the Cyclostomatous type, which begin in the Silurian epoch, are more or less persistent throughout all the geological changes of the earth, those of the Cheilostomatous type had their origin (very faintly developed, however) in the Neocomian strata; for d'Orbigny records only three species—one in each—in his first three stages of the Cretaceous epoch. This opinion, however, has to be modified in the light of recent investigations in this country and in America; but even now Cheilostomatous Polyzoa are very rare in rocks below the Cretaceous. In the absence, therefore, of Cheilostomatous Polyzoa in the Faringdon material, and the preponderance of Cyclostomatous forms, I am inclined to infer that the Faringdon Polyzoa fauna, in spite of its mixed and anomalous character in the so-called 'Neocomian Sands,' were derived from the disintegration of rocks before, rather than after, the epoch of the Upper Chalk; and in all probability the identifications in the Catalogue of Senonian and Danian species, given above, well merit reconsideration by some competent authority.

As regards the Polyzoa of Neocomian rocks of Louth in Lincolnshire, it may be advantageous to science if I draw attention to certain species which came into my possession some time since. In 1886 I received from Mr. Wallis Kew, of Louth, three small fragments of a polyzoon from the Neocomian clay at Donnington-on-Bain, near Louth. This species I described in 'Annals and Magazine of Natural History,' January 1887, pp. 17–19, as *Entalophora gracilis*, Goldf., var. When I began to gather together material for my papers on Cretaceous Polyzoa, I did my best to work up the history of the material sent to me. In April 1889 I wrote to Mr. Edwin Hall, of Louth, the real discoverer of the polyzoon. He wrote to me immediately and sent me his three remaining fragments. He also forwarded to me a list of Neocomian Foraminifera collected by him at Louth. In his letter, he said that most of the Polyzoan material gathered by him was sent to the Geological Museum, Jermyn Street. After this I wrote to Mr. E. T. Newton, who, in reply to my letter, enclosed answers from Mr. Rhodes respecting Mr. Hall's material; and subsequently another letter followed on the same subject from Mr. A. J. Jukes-Browne, but none of them could find this Neocomian material.

II. Polyzoa of the Gault.

Neither in the 'Catalogue of British Fossils,' by Professor Morris, nor in the 'Catalogue of Cretaceous Fossils in the Museum of Practical Geology,' is there any mention of Polyzoa from the horizon of the Gault. In Mr. Etheridge's list, however, already quoted,[1] four (?) species of Polyzoa from this horizon are recorded. Excepting one species, I have been unable to trace where the others are alluded to or described; and, as I wanted to make this report as complete as possible, I went to London in June last for the purpose of finding out all I could about these Gault species. I was informed, both by Mr. R. B. Newton and Mr. Etheridge, of the Museum of Natural History, Cromwell Road, that there were no Gault forms in that museum. Since my visit Mr. Etheridge has kindly informed me that the following are three of those mentioned in the new edition of Phillips's 'Manual'—

Berenicea (Diastopora) Clementina, d'Orb. Pal. Fr. vol. v. p. 865, pl. 636, fig. 1–2.

Berenicea (Aulopora) polystoma, Röm. 1839, Ool. pl. 17, fig. 6; and Kreid. p. 19.
=*Diastopora gracilis*, d'Orb. 1850 (*Berenicea polystoma*, d'Orb. 1852), p. 863.

Ceriocava ramulosa (*Ceriopora*), d'Orb. [1852], Pal. Fr. vol. v. p. 1017, pl. 788, fig. 11–12.
(*Chætetes ramulosus*, Mich., 1845, Icon. Zooph. p. 202, pl. 51, fig. 5.)

Unfortunately these British specimens cannot be traced.

Through the kindness of Mr. Jesson I have been able to examine a small collection of fossils from Barnwell, Cambridge. The shells are rather brittle and require careful handling; but the Polyzoan remains stand out very well on the rough coatings of the shells; and the shells themselves have a matrix of blue clay to support them. Of the locality of the fossils, Messrs. W. H. Penning and A. J. Jukes-Browne write as follows: 'At Cambridge Station and along the East Road the Gault is shown to be 120 to 130 feet thick in wells, but at Barnwell it is said to be 140 to 150 feet. Any one who stands on the surface of the Gault at Barnwell will have little doubt about its being higher than the coprolite bed at Coldham Common, and will see that its slope south-eastward is much greater than can be accounted for by dip alone. Coldham Common,

[1] Phillips, *Manual of Geology*, vol. ii. 1885, pp. 589–590.

in fact, owes its formation to the existence of a hollow in the surface of the Gault, which is here only between 110 and 120 feet thick.'[1]

The Polyzoa of the Gault, however, require working out, and in this report I am unable to give even a provisional list.

Polyzoa from the Cambridge Greensand.

For the classification of the Chalk rocks in the neighbourhood of Cambridge, a very useful 'Table of Chalk Zones' is arranged by Messrs. Penning and Jukes-Browne in the paper already quoted from (page 21). As a preface to the introduction to this 'Table' the authors remark: 'With regard to the larger divisions under which the succession of zones may be grouped, we have felt it desirable to revive the general classification proposed by Mr. S. Woodward, in 1833, for the Chalk of Norfolk. The Melbourn rock and the Chalk rock form such marked breaks in the series that it naturally falls into three main divisions—lower, middle, and upper. We may point out that these exactly correspond with those termed by d'Orbigny "Cénomanien," "Turonien," and "Sénonien," as they are defined by Dr. Barrois'[2] (pp. 20–21).

The only portion of the table that I shall quote is the section bracketed as Lower Chalk, for the purpose of showing the position of the Cambridge Greensand in the neighbourhood of Cambridge.

Lower Chalk	Bedfordshire and Bucks.	Cambridgeshire	Berkshire and Oxfordshire	
Grey Chalk.	Blocky Chalk, with curved bedding; 60 ft.	Zone of *Holaster subglobosus*; 80 ft.	Zone of *Holaster subglobosus*; 150 ft. in three divisions.	Cenomanian.
	Totternhoe stone; 10–15 ft.	Totternhoe Stone; 15 ft.		
Chalk Marl.	Totternhoe Marl; 80 ft.	Zone of *Rhynchonella Martini*; 50–60 ft.		
	(?)	CAMBRIDGE GREENSAND.	? Chloritic Marl.	

I have already written two papers on the Polyzoa of the Cambridge Greensand,[3] one in 1885, and the other in 1889. The material that I used for the purpose of those papers was derived from different places, and supplied to me by Mr. Jesson. One lot of material contained a large number of fragments of Polyzoa and other organisms, which were picked out from washings of the débris of the phosphate beds from the Coldham Lane pits. Nearly all the Polyzoan fragments from the phosphate beds were free, that is to say, they were unattached to any particular fossil. The other series of Polyzoa described by me from the Cambridge Greensand were in many respects similar to the first, but were attached to several large fossils, which were, I believe, peculiar to the Cambridge Greensand; and whatever doubt may be thrown out respecting the true horizon of the first set of forms, the same will not apply to the second set, and it was this last set only that I ventured

[1] *Mem. Geol. Survey*, Map 51 S.W.: 'Geology of the Neighbourhood of Cambridge,' p. 15.

[2] *Recherches sur le Terr. Crét. supérieur de l'Angleterre et de l'Irlande*, 1876.

[3] 'Polyzoa of the Cambridge Greensand,' *Proc. Yorksh. Geol. and Polytech. Soc.* vol. ix.; 'Further Notes,' &c. vol. xi. pt. ii.

to characterise as 'True Cambridge Greensand Polyzoa.'[1] In separating the two sets of Polyzoan remains I do not wish to enforce any classification of my own for the Cambridge beds; but only to make myself clearly understood as to my manner of procedure, and then leave the matter to palæontologists for acceptance or discussion. I will begin with the derived examples of Polyzoa first; and, as I know next to nothing about the phosphate or coprolite pits of Cambridge, it may be well to refer the student to several sections of these beds as given in the Memoir already quoted from, and which will be found on pages 35 to 38. Of 'Coldham Common' I have already quoted a passage from the same Memoir.

III. Polyzoa of the Cambridge Greensand, or Phosphate Beds. Unattached forms (A).

Cyclostomata, Busk.

1. Proboscina angustata, d'Orb. (*Stomatopora gracilis* (?), Vine, Cambr. Green., 1888).
2. Diastopora fœcunda, Vine } (Cambr. Greensand Papers, 1885–1889, Proc. Yorks. Geol. Polytech. Soc.)
3. „ „ (*congesta* stage) } (Cambr. Greensand Papers, 1885–1889, Proc. Yorks. Geol. Polytech. Soc.)
4. „ Clementina, d'Orb. Ib.
5. „ megalopora, Vine, Ib.
6. Entalophora proboscidea, Edw. (var. raripora, d'Orb.), Ib.
7. „ „ var. elegans, Vine, Ib.
8. „ Jessoni, Vine, Ib.
9. „ neocomiensis, d'Orb. Ib.
10. „ lineata, Beissel, Ib.
11. „ „ var. striatopora, Vine (Entalophora striatopora, Vine, 1885).
12. „ gigantopora, Vine, Cambr. Greensand Papers, 1885 and 1889.
13. Filisparsa ornata, Reuss, Ib.
14. Idmonea dorsata (?), Hag. Ib.
15. Truncatula repens (?), Hag. Ib.
16. Osculipora plebeia, Novák, Ib.
17. Domopora polytaxis (?), Hag. Ib.
18. Lichenopora radiata, Aud. Ib.
19. Umbrellina (Lichenopora) paucipora, Vine, Ib.

Cheilostomata, Busk.

20. Membranipora Dumerili, var. Cantabrigiensis, Vine, Cambridge Greensand Papers, 1885 and 1889.
21. „ cretacea, d'Orb. Ib. 1889.
22. „ „ var. Francqana, d'Orb. Ib.

[1] This was not, owing to a misprint, quite so clearly stated in the second of my two papers already referred to. The ambiguity was pointed out to me by Mr. Jukes-Browne. The passage referred to is at page 252: 'The second group of Polyzoa are *derived* probably from erosion or denudation of rocks of the ages of the Cambridge Greensand and Lower Chalk.' A portion of the passage had been erased in my original MS. after the word '*derived*.' This erasure and the present note will, I hope, make matters clear.

23. Microporella antiqua, Vine, Ib. 1885.
24. Lunulites cretacea (?), Ib.

In the material already alluded to there were many fragments of Polyzoa, but those of the species numbered 1, 14, and 23, in the above list, were unique; some of the others were abundant, and some few were rather rare. The most characteristic of the whole were: *Entalophora lineata*, var. *striatopora*, Vine; *Osculipora plebeia*, Novák; and *Diastopora fœcunda*, Vine. *D. megalopora*, Vine, was rare; *Membranipora Dumerili*, var. *Cantabrigiensis*, Vine, fairly abundant.

Associated with these free forms of Polyzoa were an immense number of *Foraminifera*, *Entomostraca*,[1] *Brachiopoda*, and other organisms. The Foraminifera and Entomostraca were catalogued in the second paper on the Cambridge Greensand Polyzoa.

IV. Polyzoa attached to Cambridge Greensand Fossils (B).

(The fossils are *Radiolites Mortoni*, Mant.; *Ostrea cunabula*, Seeley; *Pharetrospongia Strahani*, Sollas.)

1. Stomatopora linearis, d'Orb., var. Mortoni, Vine. } Adherent to *Radiolites Mortoni*.
2. „ graciliformis, Vine. } Adherent to *Radiolites Mortoni*.
3. Proboscina dilatata, d'Orb., var. Cantabrigiensis, Vine. } Adherent to *Radiolites Mortoni*.
4. „ ramosa, d'Orb. } Adherent to *Radiolites Mortoni*.
5. „ gigantopora, Vine. Adherent to *Pharetrospongia Strahani*.
6. Diastopora fœcunda, Vine. On *Ostrea*, *Radiolites*, and *Pharetrospongia Strahani*.
7. „ Hagenowi, Reuss. On *Radiolites*.
8. „ megalopora, Vine. On *Ostrea cunabula*.
9. Lichenopora radiata, Aud. On *Pharetrospongia Strahani*.
10. Membranipora Dumerili, var. Cantabrigiensis, Vine. (Fine colony.) On *Radiolites Mortoni*.
11. „ cretacea, d'Orb. On *Ostrea cunabula* and *Radiolites Mortoni*.
12. „ „ var. Francqana, d'Orb. On *Radiolites Mortoni*.
13. Lunulites cretacea (*so called*). Abundant on the outer shell of *Radiolites Mortoni*.

The counterpart of this peculiar fauna only came into my possession on June 15, 1890, consequently I have not been able to allude to the species before. During a visit to Professor T. Rupert Jones, F.R.S., on the above date, he placed in my hand a small tube containing a number of fragments which had been picked out from the Chalk detritus, or Chalk-marl, of Charing, Kent, which is briefly referred to in the text, more particularly in a note (by 'W. H.') on page 2 of his 'Monograph of the Entomostraca of the Cretaceous Formation of England.'[2] The note referred to states: 'The village of Charing stands on a bank of Chalk detritus, composed of fragments of white and grey chalk, which gradually

[1] See 'Further Notes on the Polyzoa of the Lower Greensand,' &c., *Proc. Yorks. Geol. Polyt. Soc.* vol. xi. pt. ii. pp. 272–274.

[2] Palæontographical Society, 1849. The note is by the late William Harris, Esq., F.G.S., of Charing, Kent.

decrease in size from blocks of one or two feet in diameter, lying at the top, to very minute fragments, succeeded by still finer particles forming a clay bed; which in general reposes on the chlorite marl (Glauconite). This bank extends from the southern escarpment of the adjacent hills, which form part of the northern boundary of the Weald of Kent, in a gradual descent southwards for more than half a mile, where a hollow is formed occupying an area of about fifteen acres, and surrounded by Chalk detritus, except at one point, where a rivulet carries off the streams from the Chalk hills. In this hollow beneath the vegetable soil, and also under the banks of detritus, lies the clay-bed above mentioned, varying from one to twelve feet in depth, of a greyish colour and tough consistence, and containing nodules of undecomposed white and grey chalk and of ochreous and argillaceous substances. This bed abounds with many varieties of Amorphozoa, Zoophyta, Annelida, Polythalamia, Entomostraca, &c. . . . From its general and palæontological characters, this bed would seem to have been formed from the washings of the neighbouring Chalk hills at the time they received their present undulated contour.' Professor Jones regards the 'detritus' as consisting mainly of Chalk marl.

In their 'Supplementary Monograph on Cretáceous Entomostraca,' 1890, Professor T. Rupert Jones, F.R.S., and Dr. George Jennings Hinde, F.G.S., further remark on the same bed at page vi, and on the same page they refer to the 'Greensand of Cambridge,' thus: 'This bed of glauconitic marl, formerly supposed to be on the horizon of the Upper Greensand, is now known to represent the so-called chloritic or glauconitic marl, and to be really the base of the Chalk marl, which rests here on an eroded surface of Gault.' The Polyzoa of the 'Charing detritus' are so remarkably like those of the Cambridge Greensand that one naturally supposes a common origin for the two faunas. Some of the species which are common at Cambridge are rather rare at Charing; but the most characteristic Polyzoa of the two deposits are *Entalophora lineata*, var. *striatopora*, Vine, and *Umbrellina paucipora*, Vine. These are rather common in both deposits.

V. Polyzoa of the Chalk Detritus, Charing, Kent.

In his 'Catalogue of British Fossils,' Mr. Morris enumerated six species of Polyzoa from this deposit on the authority of Mr. W. Harris. I give these first:—

1. Cricopora annulata, Reuss, Böhm. Kreid. pl. 14, fig. 2–3.
2. Escharina dispersa, Reuss, Ib. pl. 15, fig. 26.
3. Hornera carinata, Reuss, Ib. pl. 14, fig. 6.
4. Pustulopora echinata, Reuss, Ib. pl. 14, fig. 4.
5. ,, madreporacea, Goldf., Blainv. 'Manuel,' p. 70, fig. 5. Reuss, Böhm. Kreid. pl. 14, fig. 5.
6. Vincularia Bronnii, Reuss, Böhm. Kreid. pl. 15, fig. 30.

The following temporary list of species, derived from the Jones-Harris material already alluded to, is given on my own authority. The list is neither classified nor complete:—

Genera and Species	In the Charing Detritus	Found also in the	
1. Entalophora lineata, Beissel, var. striatopora, Vine	Very common .	Cambridge	Greensand
2. Entalophora proboscidea, Edwards	Many examples	,,	,,
3. Entalophora proboscidea, var. elegans, Vine	Not common .	,,	,,
4. Entalophora proboscidea, var. delicatula, Vine	Rare . . .	,,	,,
5. Filisparsa ornata, Reuss .	,, ...	,,	,, (rare)
6. Laterotubigera, sp. . .	,, ...	,,	,,
7. Umbrellina paucipora, Vine .	Common . .	,,	,,
8. ,, ,, variety	Rare . . .	,,	,,
9. Melicertites, sp.	,, ...		
10. Ceriopora, sp.	,, ...		
11. Osculipora plebeia, Novák .	Very rare . .	Cambridge (common)	Greensand
12. Vincularia Bronnii, Reuss (or variety)	,, ,, . .		
13. Vincularia, sp. . . .	,, ,, . .		

By comparing these lists of the two faunas, it will be seen how closely they agree on the whole; but in the material I received from Professor Rupert Jones we have no *Diastoporæ* nor *Membraniporæ*.

VI. Upper Greensand Polyzoa.

The Upper Greensand Polyzoa, of which there are a good number of examples in the Museum of Practical Geology, differ very materially from the Lower Greensand forms. Professor Beete-Jukes, Manual Geol., p. 506, says: 'This set of beds often resembles the Lower Greensand in lithological character, but the same caution is to be used in taking its designation for a *name* only and not for a *description*. . . . It has been surmised that the Upper Greensand may be in part a shore deposit, and therefore contemporaneous with, rather than preceding, the lowest beds of the Chalk; but, wherever the two are together, we always find the Upper Greensand underneath the Chalk-marl.' Some of the Polyzoa are rather characteristic of the deposit, while other forms are similar to those found in the Faringdon beds. One particular form, *Ceriopora polymorpha*, Goldfuss, is very characteristic, but the form designated by Jukes *Cricopora gracilis*, though also characteristic, has rather a wide range. The Upper Greensand Polyzoa in the Jermyn Street Museum have been gathered from several localities, but chiefly from Warminster and Devizes. I give the whole of the species catalogued by Professor Morris and others, hoping to be able to re-examine them carefully at some future time.[1]

1. Diastopora Sowerbii, Lonsdale.
2. ,, tubulus, d'Orb.
3. Bidiastopora lamellosa, d'Orb.
4. Laterotubigera cenomana, d'Orb.
5. Spiropora cenomana, d'Orb.

[1] Since this was written I learn by letter 'that the considerable collection of Upper Greensand Polyzoa in the Woodwardian Museum was formed by Prof. Seeley.' This collection I have not seen.

6. Cricopora gracilis, Goldf.
7. Entalophora ramosissima, d'Orb.
8. „ Francqana, d'Orb. (Clausa id. d'Orb.)
9. „ micropora, d'Orb. (Clausa d'Orb.)
10. Retepora (Idmonea) clathrata, Goldf.
11. Heteropora cryptopora (Multicrescis).
12. Petalopora pulchella, Lonsd. (*Cavea regularis,* d'Orb.).
13. Radiopora pustulosa, d'Orb.
14. Domopora tuberculata, d'Orb.
15. Ceriopora polymorpha, Goldf.
16. Truncatula pinnata, Röm.
17. Eschara Cybele, d'Orb.

VII. Polyzoa of the Blackdown and Haldon Beds.

The Rev. W. Downes, in a paper on 'The Zones of the Blackdown Beds,'[1] mentioned four species of Polyzoa preserved in the Bristol Museum.

1. Heteropora dichotoma, Blainv.
2. „ cryptopora, Goldf.
3. Ceriopora gracilis, Goldf.
4. Radiopora bulbosa, d'Orb.

The species 1 to 3, with others not yet catalogued, are found also in the Haldon beds of Devon. The *Radiopora bulbosa* may be picked up in large masses as water-worn pebbles on the Devonshire coast; and I have a very fine example thus derived, which was given to me some years ago by Mr. Downes, but the Haldon species still await investigation.

VIII. Polyzoa of the Red Chalk of Hunstanton.

It is not my intention, here or elsewhere, to enter upon any lengthy discussion as to the origin or the exact geological horizon of the Red Chalk. It will, however, be an advantage if I preface my Red Chalk list of Polyzoa with a few remarks on this very peculiar deposit. The Rev. T. Wiltshire, writing in 1859 on the Red Chalk of England,[2] says: 'This stratum . . . nowhere forms a mass of any great thickness or extent; perhaps if thirty feet be taken as its maximum of thickness, four feet as its minimum, and one hundred miles as its utmost extent in length, the truth will be arrived at. It may be said, also, to be peculiar to England, for the *Scaglia,* or Red Chalk, of the Italians has little in common with that of our country. The two differ widely in appearance, in situation, and in fossils' (p. 261). A good sketch map showing the extent of the Red Chalk as it is traced in the East of England (from Hunstanton to Filey), and a fine view of Hunstanton Cliff, embellish Mr. Wiltshire's paper. Only three species of Polyzoa are mentioned by Mr. Wiltshire.

1. Idmonea dilatata, d'Orb. Terr. Crét., tab. 632; Speeton.
2. Diastopora ramosa, Dixon, Geol. Sussex, p. 295; Hunstanton.
3. Ceriopora spongites, Goldf. Petrifac. p. 25, t. 10, fig. 14; Speeton.

[1] *Quart. Journ. Geol. Soc.* Feb. 1882, pp. 75–94.
[2] *The Geologist,* 1859, pp. 261–278.

In 1864 Prof. Seeley published a list of Red Chalk fossils,[1] in which were included seven species of Polyzoa. These, together with other new Red Chalk fossils, were described in 1866,[2] and in my present list (p. 395) three additional species which may be regarded as new are given—partly upon the authority of Prof. Seeley.

In a second paper by the Rev. T. Wiltshire[3] the author adds to his former list three more species of Hunstanton Polyzoa; and a very full list of Red Chalk fossils, including five species of Polyzoa, is given as an appendix to Mr. Whitaker's Presidential address to the Norwich Geological Society.[4] Besides these, I am not aware of any other papers in which Red Chalk Polyzoa are mentioned. I am very sorry that these papers were overlooked by me when I wrote the monograph referred to on p. 395 of the present report.

No disrespect is intended towards those authors who have written on the Red Chalk (and a long list of papers are before me); but, as Messrs. W. H. Hill and A. J. Jukes-Browne have summarised much of the previous literature on the subject, I will, for brevity, only quote remarks from their two latest papers. The reason will be at once apparent, when I say that at the present time these authors regard the Hunstanton Limestone as being the equivalent of the Gault; and, if so, the Polyzoa which are adherent to the Red Chalk fossils belong to the Gault epoch also. All the true British Gault species known to me, with which I can compare these faunas, have been tabulated in the present Report. D'Orbigny, in his elaborate analysis of the Cretaceous Polyzoa, catalogues only sixteen species in his 'Albien' stage, three of which we meet with in the British fauna :—

1. Multelea gracilis, d'Orb. (*Cricopora gracilis*, Michelin), Terr. Crét. p. 645.
2. Multicrescis mamillata, d'Orb. Ib. p. 1076.
3. " Michelini, d'Orb. (*Heteropora cryptopora,* Mich.), Ib. p. 1075.

Novák,[5] in his long list of the Bohemian Polyzoan fauna, does not mention Gault species; and Marsson[6] mentions only one Gault form, *Sparsicavea irregularis*, d'Orb., and this species ranges into Turonian and Senonian strata.

In their paper 'On the Lower Beds of the Upper Cretaceous Series in Suffolk and Norfolk,' Messrs. Hill and Jukes-Browne[7] remark (p. 592): 'We are now in a position to indicate the bearing of our work on the debated question of the exact age of the Red Chalk. In the absence of anything like ordinary Gault, Upper Greensand, or Chalk-marl at Hunstanton, the remarkable stratum which there lies at the base of the Chalk has been referred by different observers to each of the formations which appeared to be missing,—to the Gault by most of the early writers and by Mr. Wiltshire, to the Upper Greensand by Professor Seeley (on the strength of its fossils being similar to those of the Cambridge Greensand), and lastly to the Chalk-marl by Mr. Whitaker. Everyone, however, has discussed the question from a local point of view, founding their

[1] *Ann. Mag. Nat. Hist.* vol. xiv. pp. 276, 278.
[2] *Ibid.* vol. xvii. p. 181.
[3] *Quart. Journ. Geol. Soc.* vol. xxv. p. 187.
[4] *Proc. Norwich Geol. Soc.* vol. i. part vii. 1883.
[5] *Bryoz. Böhm. Kreidef.*
[6] *Die Bryoz. Weiss. Schreibkreide Insel Rügen.* 1887.
[7] *Quart. Journ. Geol. Soc.* vol. xliii. p. 544.

arguments mainly upon a consideration of the rock and its fossils as seen at Hunstanton.' Further on (p. 593), the authors state certain premises, the last of which is as follows: The fossils of the Red Rock at Hunstanton 'are chiefly Gault species, and are such as would constitute a deep-sea fauna contemporaneous with that of the shallower and muddier water in which the Gault of the South of England was formed. . . . From these premises we come to the inevitable conclusion that the Red Rock of Hunstanton must be the equivalent of the Gault, and not of its upper division only; but that it is a condensed representative of both Lower and Upper Gault, formed outside of the limits of the area reached by mud-bearing currents.'

Having given these statements on the authority of Messrs. Hill and Browne, I will now leave the whole consideration of the question as to the horizon of the Red Chalk Polyzoa to others who may be better able to decide; but, instead of giving a consecutive list of the species as already described by me from the Hunstanton Red Rock,[1] I will break the list into two parts, showing, first, the species peculiar to the formation; and, secondly, the species whose identities approach nearest to the species already described and illustrated by d'Orbigny and others. This desire on my part to keep down the introduction of too many 'new species' into my list, and so loading our nomenclature, has its disadvantageous side, for even those forms which I have placed under d'Orbigny's names may merit separate illustration, as well as the notes on their peculiarities already given in the paper referred to.

I. *Species new, and, so far as yet known, peculiar to this Horizon.*

1. Proboscina irregularis, Vine. This species varies much on different fossils.
2. " uberrima, Vine.
3. " (gracilis, Reuss), var. Reussii, Vine.
4. " subelegans (approaches nearest to *P. subelegans*, d'Orb., Pergens).
5. " Hunstantonensis, Vine. Abundant and peculiar.
6. " " var. ampliata, Vine.
7. " Jessoni, Vine.
8. " gigantopora, Vine.
9. " dilatata, var. Cantabrigiensis, Vine. (Only a cast found on a Red Chalk fossil.)
10. Diastopora Hunstantonensis, Vine. Most abundant, on various fossils.
11. " " variety. The 'cells' differ slightly from those of the type.
12. " fœcunda, Vine. Not common.
13. " Jessoni, Vine. Very fine.
14. " (Berenicea) contracta, Seeley.
15. " (Cellulipora) sulcata, Seeley.
16. Reptomulticava favus, Seeley.
17. Membranipora Gaultina, var., Vine.

[1] *Quart. Journ. Geol. Soc.* August 1890, pp. 454–486, one quarto plate xix.

II. *Species which, though somewhat peculiar, approach the nearest to the following.*

1. Stomatopora gracilis (?), Edwards. Unlike the *S. gracilis*, Edw., of the Upper Chalk.
2. ,, divaricata, Römer.
3. ,, granulata, Edw.
4. ,, ,, var. incrassata, d'Orb.
5. ,, ramea, Blainv.
6. ,, longiscata, d'Orb.
7. ,, linearis, d'Orb.
8. Proboscina angustata, d'Orb.
9. ,, rugosa (?), d'Orb.
10. ,, Bohemica, Novák (near).
11. ,, Toucasiana (?), d'Orb.
12. ,, ramosa (?), d'Orb.
13. Diastopora radians (?), Novák.
14. ,, papillosa (?), Reuss.
15. Unitubigera papyracea, d'Orb.
16. Ceriopora micropora,[1] Goldf.
17. Reptomulticava simplex, d'Orb.
18. ,, collis, d'Orb.
19. Zonopora variabilis, d'Orb.
20. ,, irregularis, d'Orb.
21. Multicrescis variabilis, d'Orb.
22. Unicavea collis, d'Orb. (*Actinopora collis*, d'Orb.).
23. Membranipora (?) simplex, d'Orb. (*Hippothoa simplex*, d'Orb.).
24. ,, fragilis (?), d'Orb.
25. ,, elliptica (?), d'Orb.
26. ,, obliqua, d'Orb.

Besides the above, I have a few examples of Red Chalk Polyzoa which are still undescribed on account of their fragmentary condition, and laid aside in the hope of better material turning up.

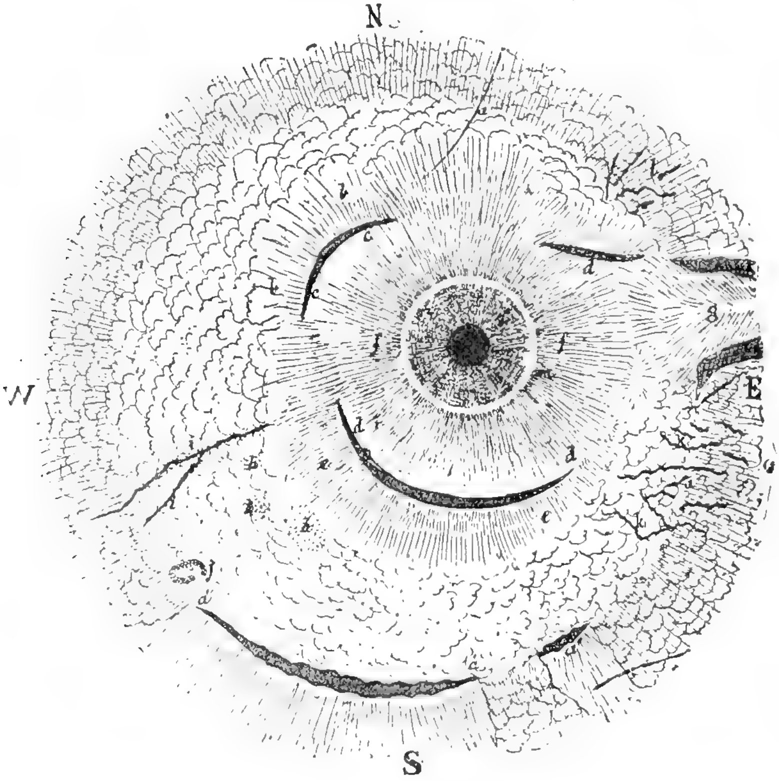
There is still very much to be done in describing the Polyzoa of the Cretaceous beds, and it seems to be useless as yet to prepare lists of species found in the Upper Chalk of Great Britain. I have already in my possession a quantity of material to describe from the Chalk overlying the Red Chalk of Hunstanton, and from the Upper White Chalk of Chatham and elsewhere. I may be allowed to say in conclusion, that I am preparing a Monograph of the Cretaceous Polyzoa, and that any assistance given to me, either by the loan of examples, or by lists of species in local museums, will be thankfully received and fully acknowledged.

[1] In these lists I have left out the *Entalophora* (?) sp. and *Heteropora* (?) sp. of my paper.

Report of the Committee, consisting of Mr. H. BAUERMAN, Mr. F. W. RUDLER, Mr. J. J. H. TEALL, *and* Dr. H. J. JOHNSTON-LAVIS, *appointed for the investigation of the Volcanic Phenomena of Vesuvius and its neighbourhood. (Drawn up by* Dr. H. J. JOHNSTON-LAVIS, *F.G.S., Secretary.)*

State of Vesuvius.—The eruptive vent to the N.N.W. of the crater of May 1889 soon moved slightly eastwards, where, with slight variations, it remained. During September the activity rarely rose to the 2nd degree, and presented no phenomena of importance. In October much the same state was maintained as far as could be seen from Naples. The weather in the early part of the month was exceedingly cloudy, and although the Geologists' Association's excursion to the crater was one of the first objects on the programme for their trip to the volcanic regions of Southern Italy, it was not till the 12th that a suitable day was forthcoming. Neither was that at first very favourable for the purpose, there being much cloud and wind. Fortunately, at the moment of our arrival at the crater the clouds cleared off, and the party were able to examine the volcano to perfection. I have visited the crater over sixty times, and only on one other occasion was the eruptive mouth more susceptible of a close approach and examination. By making the circuit of the crater plain on the S. side (fig. 1) the vent was approached from the E. until the party reached a spot about 10 or 12 m. from the vents, to do which they had to traverse the small mound and the remnants of another low crater ring covered up between October and the date when fig. 1 represented the mountain summit. The crater rim *f* of the eruptive cone, as shown in the figure, was then very much lower, and enclosed a shallow basin-shaped crater, so that when standing at *m* we were not more than 5 m. above the double vent, which was about 10 to 12 m. distant. The two vents were situated on a line N. and S.; the largest about 3 m., the smaller about 1½ m. in diameter. Both were ejecting blasts of dry vapour, with fragments of pasty lava, which were fortunately very small, and carried to the W. by the wind. These vents strongly reminded one of two enormous Bessemer converters being rather roughly worked. So easy was the approach that I was able to go and return several times to conduct sections of our party to the inner crater edge, and amongst these were various ladies and a veteran geologist of fourscore years. Some 50 or 60 m. down the eastern slope of the great cone lava was oozing forth in a small stream, with about a sectional area of half a square metre, and at the rate of one metre in 20 seconds, which would give an outflow of about 2,160 cub. m. in 24 hours, or, subtracting something for viscous drag and retardation along the sides and bottom, let us call it 2,000 cub. m. The daily outflow rarely amounts to a smaller quantity than this, so that if we calculate this as the daily average from May 5 to December 25, the respective dates when the outflow commenced and finished—in all 234 days—we have the considerable quantity of 468,000 cub. m., or nearly half a million cubic metres of lava represented by a cube whose sides are 78 m., or a steep side cone over 100 m. high. The major part guttered over and remained attached to the slopes of the cone. The point of issue was about one quarter way down the great cone, and in this outflow the lava dribbles only a few yards; great bosses and buttresses are built up so as to constitute very important additions, both in bulk and strength, to the cone. During this month of October a little progress was made in raising and enlarging the eruptive crater ring into a low cone; but during the following month of November the activity arose frequently to the 2nd degree, and consequently

FIG. 1.—Sketch Plan of the Summit of the Great Cone of Vesuvius on April 11, 1890.



Limit of the 1872 crater where overflowed by lava, *a*, and where still visible, *a'*; *b*, remnant of cone of 1885–6; *c*, part of crater edge of May 1886; *d*, crater of May 1889; *e*, part of cone of eruption up to end of April 1889; *f*, cone of eruption from May 1889 to April 1890; *g*, fissure of May 1889; *h*, yellow patches of decomposing lava, scoriæ, and dust, marking situation of old hot-air passages and fumaroles; *i*, fissure emitting HCl vapours; *j*, guides' shelter; *k*, numerous fissures on S.E. edge of great cone; *l*, other fissures on N.E. edge of great cone.

the growth went on more rapidly. This increased activity was rather an indication of the increasing obstruction to the lateral outflow, so that lava had risen in the chimney. The obstruction, and probably other circumstances, culminated on December 2, when the activity rose from the 3rd to the 4th deg. and lava stopped flowing; but after a few hours the fluid rock again forced its way out, and activity dropped to the 1st degree. Towards the middle of the month the activity again rose to the 2nd degree, and remained so, when visible, until the 23rd. On that day the smoke issued in a puffy and intermittent manner; in the evening there was cloud-cap, but the next day the activity rose to the 3rd degree, coincident with a marked diminution in the outflow, which during the next days entirely stopped.

In the early part of January the activity was rarely above the 1st degree; the crater edge was tumbling in, so that on the 9th it was observable that slight truncation of the eruptive cone was visible. The low lava level, and consequently the 1st degree of activity as well as the crumbling in of the inner slopes of eruptive cone, I am inclined to attribute to an extension of the S.E. dyke, as the fissures marked *k* in fig. 1, lying above it, were increased in size and number about this time. For the next four weeks the volcano was very quiet, showing usually about the 1st degree of activity. On February 9 the new small crater cavity of a month before was yet little altered, the walls still crumbling in and the eruptive vent situated under the eastern edge in the direction of the rift in the side of the great cone from which the last lava had issued. Till the end of the month little could be seen from Naples.

During March more reflection at the crater was visible from Naples, which indicated the repair of the eruptive cone, and the rise of lava level within the chimney. Unfortunately during February, March, and April several attacks of illness and the resulting weakness prevented me from making observations with that regularity that I should have wished.

During May a further marked increase of activity was visible, so that the eruptive cone grew rapidly in height. On the 11th, when I visited the crater, the eruptive cone had already considerably surpassed the height of the crater edge of May 1889. The general arrangement of the eruptive apparatus and summit of the great cone can be seen from the semi-diagrammatic plan, fig. 1.

As the cone of eruption rose in height, so also did the level of the lava, so that cakes of lava were ejected very abundantly. The activity therefore often equalled the 2nd to 3rd degree.

The month of June showed little or no variation in the state of the mountain. During this month I quitted Naples on a trip to Iceland, and my friend and pupil Mr. L. Sambon kindly undertook to continue the observations on Vesuvius, and therefore for the following information I am gratefully indebted to him, knowing as I do his precise method of observation.

The quiet state of the volcano continued through July till August 5, the activity rarely rising above the 1st degree, but on that and the 6th and 7th of the month the 3rd and 4th degrees prevailed. On August 7, at noon, following small local earthquakes and *boati*, the summit of the mountain was split open along the S.E. fissures in the crater-plain, which now was prolonged right through the side of the eruptive cone. Lava issued from this new rift at the foot of the cone of eruption; the first gush, however, soon stopped and cooled, but later in the same day the lava burst out afresh about 50 m. lower down (*and therefore on the slopes of the great cone*) and continued to flow. On the 9th a distinct reflection was visible on Vesuvius from the flowing lava. My friend visited the scene of the outburst on July 12, and found the cone of eruption with its edges undermined so as to be overhanging, due no doubt to the sousing about of the lava at a lower level in the chimney. The ejections were, as usually the case after a lateral outburst, what is commonly called ashy, that is, no longer composed of soft hot lava cakes, but the broken-up sides of the chimney and eruptive cone projected as dust, sand, lapilli, and breccia by the escaping vapour which whiffed out continually.

The cone of eruption lost little in height, though the undermining would no doubt result in a collapse of part of it. The lava flowed nearly down to the foot of the great cone.

On the evening of July 12 the lava was still flowing, though hardly any activity was visible at the top of the cone, though sufficient to show that the fluid lava column had not sunk far from the summit. On the 13th the outflow diminished as the activity at the summit rose fully to the 1st degree, and so remained till August 9.

Drainage-works in Naples.—Although frequent visits have been paid to the numerous new tunnels beneath the streets of the town, so far little of interest from a geological point of view has been brought to light.

Funicular Railway of Monte Santo.—The continuation of the railway below the bottom opening of the tunnel unfortunately has been only in surface soil, so that the complete relations of the pumice and dust-beds beneath the pipernoid tuff cannot be fixed in a downward direction. An opening near the entrance to the tunnel shows the following beds beneath the bottom of the white pumice underlying the grey pipernoid tuff. These are as follows, from above downwards:—Old vegetable soil, with a felspathic sand band a short distance beneath its surface. It passes down into compact buff dust with white pumice. Next comes another compacted dust-bed, passing down into white pumice, in all about 0·50m. This is followed by about 1·20 m. of beds, or rather bands, of varicoloured pumice, with intervening dust-beds. The lowest visible member is about 1 m. of small white pumice. These beds are probably the oldest volcanic products of the Phlegrean Fields exposed at the surface, with the exception of the Rione Amedeo tuffs.

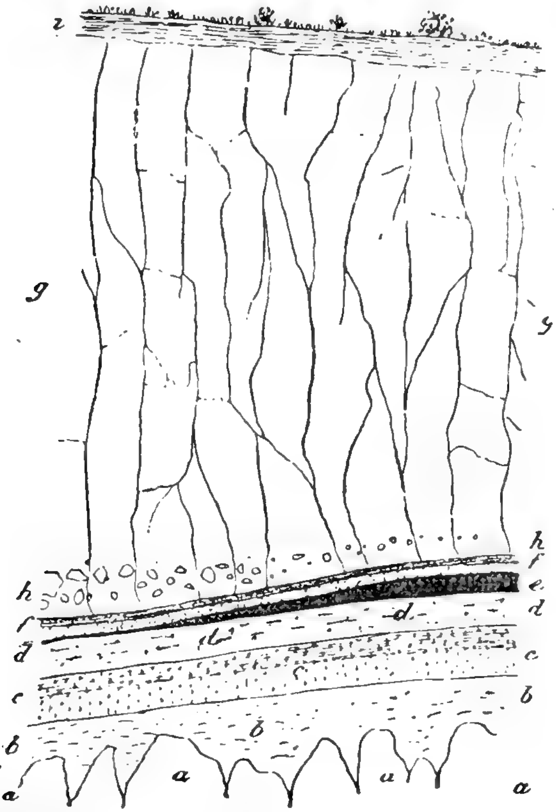
Province of Naples.—Continuing my investigations of the chronological stratigraphy of the volcanic products of the Neapolitan area, it is with much pleasure that a considerable amount of valuable additions of facts bearing on this point has come under my observation. Professor A. Scacchi, continuing his mineralogical investigations on the metamorphosed blocks of limestone enclosed in the pipernoid tuff, has described those of Puccianello near Caserta. He also touches upon their geological relations, referring them to a local eruption at that spot. As this is a report, and elsewhere I have combated those opinions, I shall limit these remarks to my own observations and the conclusions I am led to by them.

At the conjunction of two or three shallow but steeply inclined gorges in the limestone are the remains of an old deposit of pipernoid tuff attaining considerable thickness in consequence of being a talus formed from the slopes above when stripped of their subaerial covering of volcanic dust soon after its ejection. This mass of tuff has been very extensively quarried, and the highest pit exhibits the relations of the quarried tuff to the limestone. From the accompanying details and sketch section these relations can be easily understood.

The identity of the beds underlying the pipernoid tuff of Puccianello and that of the Monte Santo Funicular Railway tunnel cannot for one moment be doubted, and fully confirms my former conclusion drawn from much more imperfect sections elsewhere.

Near the bottom of the pipernoid tuff of Puccianello is a layer of old limestone fragments, &c., now metamorphosed to fluorides and silicates. The band of these runs near and parallel to the under surface of the tuff, and the layer of fragments is more common at the lower end of the band, indicating that they were carried down the slopes above, being nothing more than the loose surface fragments of the limestone slopes above. Their occurrence near the bottom of the tuff is just what we should expect to find under those conditions. The limestone surface

FIG. 2.



i, Vegetable soil, Vesuvian dust and lapilli, &c., variable; *g*, pipernoid tuff with a band of fluoriferised limestone fragments near the bottom, which is inclined, and the larger inclusions are nearer the lower part of the slope, 15 to 30 m.; *f*, pumiceous sand redder and more argillaceous at the top, 0·30 m.; *e*, black carbonaceous earth with a few fragments of white pumice. This bed thins out to nothing at the lower end of section, 0·40 m.; *d*, ochreous earth with white pumice, 0·65 m.; *c*, white pumice, browner and dustier at the top, 0·85 m.; *b*, yellowish or reddish brown earth variable from 0·50 to 2·00 m.; *a*, limestone rounded and rilled, and with gaping clefts, as if exposed to action of acids. The surface gives a fluorine reaction, and is spongy to some depth.

beneath the section is also of great interest. It is furrowed and rounded as if a stream of acid water had flowed over it, and much resembles a white marble sink of a laboratory etched out and furrowed by the acid liquids flowing over it. A similar condition can often be seen on the Neapolitan water-sellers' marble counters in Naples from the action of the waste lemon-juice. The old cracks of the limestone are open and gaping, whilst the surface is rotten and porous from 1 to 5 cm. more in depth, and the thin crust affords a marked fluorine reaction. All these characters point to the fact that this limestone has been exposed to chemical corrosion not of a usual kind, and that one of the corrodents was a compound of fluorine. But, as may be seen by the section, this fluoriferous pipernoid tuff is not in contact with the limestone, and could not have acted upon it directly, and therefore the probability is that this chemical erosion was brought into action by rainwater percolating through the tuffs having dissolved out the acids, probably of fluorine, chlorine, and sulphur, from the ejectamenta that formed the pipernoid tuff.

The fragments of scoriæ and porphyritic vitreous trachyte that enter into the composition of the pipernoid tuff are comparatively very large, and would seem to indicate the prevalence of a strong wind.

Marine terrace of Castellamare.—A proper examination of this is prevented to a large extent by talus, vegetation, and buildings; but I had the good fortune lately to find a small spot in a private garden near 'Sommazzarello' where there is an entrance to an old tunnel quarry in the pipernoid tuff which forms the basis of the cliff. This marine terrace is, on account of its height and age, so far as can be made out, contemporaneous with that at Pozzuoli, known as the Starza, and which overlooks the Serapeum, and, like it, has been built under, against, and over by the Romans, at that time forming part of the town of Stabiæ. At the section in question the base of the cliff is composed of a bank of pipernoid tuff, the bottom of which is not visible in the hole 2 m. deep, which also forms another 4 m. at the cliff bottom. Superposed upon this are traces of the *museum* breccia, as indicated by the included rock fragments; but the main mass is a red pisolitic earth, some of the pisolites attaining the size of an egg. The appearance of a few well-rounded pebbles indicates water erosion, but whether fluviatile or marine I could find no certain indication. Associated with the fragments of the *museum* breccia are many pieces of limestone, which of course are to be expected in this locality. The main mass of the cliff above is made up of a series of beds of limestone pebbles interstratified with bands of tuff and tufaceous earth. These tuffs will, I think, by a more careful examination, prove to be chiefly of Vesuvian origin. At the top of the cliff there is a marked stratum of plinian pumice (Phase VII., Period 1), which of course buried Stabiæ. This section shows us that the grey tuff was ejected before all the other visible components of this cliff, and at a time, or possibly previous to the time (if there were several oscillations of level), when the sea-surface stood above the level of the platform of this terrace, and at no great distance eroded the foot of Monte Barbaro. This, therefore, is another link in the chronological chain of the Naples volcanic region.

Erratics on Capri.—My attention has been devoted to the examination of the remnants of volcanic rocks which in places mantle the Cretaceous and Jurassic limestones of the island of Capri. These tuffs are, no doubt, often a resorted mixture of the ejectamenta from different sources, and of different dates, which from time to time have reached the island, though much of the fine-grained sanidinic variety is undoubtedly to be referred to much decomposed remnants of pipernoid tuff, such as is often met with on the mainland. The principal part of the island, however, is covered by a mantle of ochreous argillaceous earth, often a metre or more in thickness, and containing nearer its bottom a poorly defined band of about 0·10 m. thick, composed of rock fragments identical with those of the *museum* breccia associated with the essential components of those ejectamenta, viz., the peculiar porphyritic obsidian and wood-like pumice. These fragments were of considerable size, and out of some pocketfuls collected during half an hour from a spot called Lima five of the largest were found to weigh 720 grammes, the heaviest one being above 200 grammes, or say $7\frac{1}{2}$ ounces, which is enormous, considering the distance of Capri from the neighbourhood of Pianura. Associated with these rock fragments I found ancient archaic pottery and stone implements, but could find nothing very definite as to their position relative to these superficial deposits.

Tuff-quarries of Fajano.—After waiting three years, the tuff cutting has again reached a section that I had admired during that time and wished to examine more minutely, for it is the most perfect of the Vesuvian deposits which overlie the pipernoid tuff in the neighbourhood. The following are the details of this valuable section from below upwards:—

Grey tuff, quarried down for at least	20·00 m.
PHASES III., IV., AND V.	
Gritty brown bed, with very few and small fragments of rolled pumice. In some spots it is finely false-bedded, and passes up into the next	0·20 m.
Brown soil with indistinct plant markings and a few fragments of pumice	1·25 m.
Pumiceous bed with a few lava lapilli	0·35 m.
PHASE VI., PERIOD 1.	
Regularly stratified vesicular compacted dust bed . .	0·10 to 0·20 m.
Very markedly stratified deposit of greyish black compact lapilli passing up into next	0·35 m.
Fine and coarse stratified vesicular compacted dust passing up into next	0·35 m.
PHASE VI., PERIOD 2.	
Yellow pumiceous sand with fragments of rolled pumice at bottom	1·80 m.
PHASE VI., PERIOD 3.	
Fine white pumice in very regular bed with little *accessory* material	0·25 m.
The same, but with much *accessory* material	0·18 m.
Fine lapilli of accessory materials of last . . .	0·20 to 0·35 m.
? Yellow pumiceous soil	2·10 m.
PHASE VI., PERIOD 3, ? AND PHASE VII.	
White pumice	0·50 m.
Vegetable soil	—

In a neighbouring quarry Phase VI., Period 4, is well represented, but the section has been for some years inaccessible, and I have not been able to examine the relationship of the upper to the lower portions. In many points of the above detailed section blocks of limestone are included which have no doubt rolled down from the mountain above, just as they did during the deposition of the subjacent pipernoid tuffs. They are subangular and porous on the surface in consequence of the action of percolating waters.

The great main-sewer works.—Returning again to the neighbourhood immediately to the W. of Naples, we meet with the sections exposed in cutting the new main sewer, which will carry the cloacal waters across the Phlegrean Fields to the Gulf of Gaeta. That portion which runs nearly parallel to the old and new grotto tunnels to the W. of Naples, so far as cut, still remains in the upper yellow Neapolitan tuff, and one point is 20 m. lower than the floor of the new tunnel, and close to the elevator shaft, which has proved the upper yellow tuff to be 60 m. thick above the causeway, and therefore giving an aggregate thickness for this deposit of at least over 80 m. This deposit, if due to a single eruption, as its homogeneity would seem to indicate, is certainly a very remarkable fact.

Where this tunnel crosses the plain from Fuorigrotta to Bagnoli great uniformity of materials has been met with, well-stratified beds of varying thickness of yellow argillaceous dust, including more or less white pumice, as well as brownish violet pozzolana and lapilli, with fragments of dark buff or brown pumice like that of the hills to the S.W. of the Solfatara predominating. Occasionally a band or two bands of dark brown scoriaceous trachyte lapilli are met with. These beds are nearly horizontal except where they approach the slopes of Posilippo. Most of these strata seem to be either subaerial deposits, or laid down in very shallow water. Fragments of lignitised wood are occasionally met with, and one overseer told me he had met with the impression of a fern leaf, but that it had crumbled to pieces.

As the tunnel approaches the outer toe of the slopes that encircle the Lago d'Agnano, at a spot more than a kilometre from the celebrated Grotto del Cane, a very serious escape of carbonic acid commenced to take place in the workings, which soon caused operations to be suspended, and such was the output of irrespirable gas that only with very powerful ventilators could the work be carried on. The length of the tunnel along which this escape takes place is very considerable, but cannot be determined until more advance is made; but, altogether, the area over which the exudation of carbonic acid gas is going on must be a very wide one, and must represent the diurnal escape into the atmosphere of an enormous quantity.[1]

The working shaft near the road to Agnano presents a section somewhat different from the others in the Bagnoli plain, since here the toe of the outer slopes of the Agnano crater is cut through. The following was the section obtained from above downwards:—

Greenish buff, pozzolana, and rolled pumice, the whole stratified horizontally but with false bedded details	5·40
Light brown pozzolana, black and vegetable soil at top	3·80
Chocolate tuffs like Bagnoli and Solfatara down to	3·00

The work, on account of the above-mentioned difficulties, has not yet been more than commenced near Bagnoli and Pozzuoli, where many technical difficulties present themselves, and geological facts of the greatest importance are likely to be brought to light. The 'Società degli Ingegneri Costruttore,' before facing these difficulties, requested me to study the region thoroughly and report thereon; and as those studies are of no uncommon interest, the substance is included in this report.

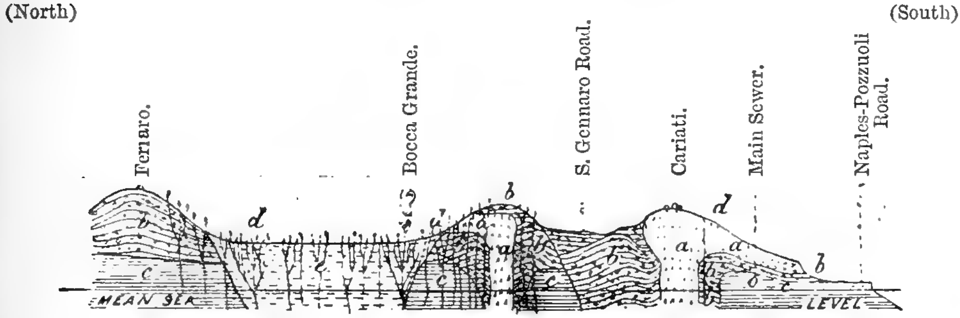
The main sewer will be a tunnel which perforates the mountains from the thermal region of Bagnoli under the slopes of the Solfatara Monte Olibano, and thence to Pozzuoli, a region where the very embers of the Forge of Vulcan have to be traversed.

[1] In 1886 an attempt was made to excavate a well by the roadside where the road from Agnano joins that from Fuorigrotta to Bagnoli, and here much 'Mofetta' was also encountered, indicating that the area of escape extends at least another half-kilometre eastwards.

The difficulties to be encountered may be classified as follows:—

1. Lithological characters of the rocks to be traversed.
2. Temperature of the rocks.
3. Exhalation of irritant and deleterious vapours and gases.
4. Thermo-mineral waters.
5. Depression of the land-level in relation to that of the sea.

FIG. 3.—Section across M. Olibano and the Solfatara near Pozzuoli.
Scale of 1 : 17,000.



a, Canals of trachyte; *a'*, trachyte streams; *b*, scoriæ and other fragmentary ejecta filling the old craters; *c*, strata of incoherent submarine pozzolana; *d*, fumaroles; *e*, argillaceous tuffs with fragments of lignite, which in part fill the crater of the Solfatara.

N.B.—The Bocca Grande is not really in the line of section, but slightly to the east.

1. *Geological structure of the region.*—Just beyond the locality known as La Pietra, towards Pozzuoli, and near the mouth of the Cumana Railway tunnel, we meet with a compact yellow tuff much resembling that of Naples, Posilippo, and Pozzuoli. This tuff, rising very abruptly from the sea-level, constitutes the promontory now traversed by a short railway tunnel. Of this tuff is constituted the base of that cliff as well as some other masses. The same tuff reappears at the entry to Pozzuoli, and of which also is composed the almost peninsular hill on which the old town stands. These fragmentary materials erupted, and since indurated by decomposition, and some of their constituents altered, as usually occurs, have subsequently been subjected to so much marine erosion as to reduce them to submarine reefs and islands at a time when the sea was at a higher level, reaching to and eroding the foot of Monte Barbaro, reducing it to its present state of ruin. The waves, in fact, undermined the foot of Monte Barbaro both in front and at its two sides, actually breaching the Campiglione crater on the east. At that epoch the shore-line reached the Montagna Spaccata, the foot of Camaldoli, and covered the plain from Fuorigrotta to Bagnoli. It was this sea that deposited those tuffs and pozzolanas which, abounding in shells and other skeletons of marine animals, now constitute in section the Starza of Pozzuoli, a terrace which extends from Monte Nuovo to the Cava Regia, interrupted by the already-mentioned tuff promontory of Pozzuoli. Other traces of this same sea-bottom, arranged as a terrace, rise behind the Lucrine Lake, near the Stufe di Nerone and behind the Bathing Establishment of Patamia. The terrace at Stabiæ, mentioned in another part of this report, is referable to the same age. It is the shore-line of this sea around the ancient tuff islands and reefs that may be studied to perfection at La Pietra.

On the irregularly eroded surface of the yellow tuff we find deposits of a great number of large boulders and pebbles of the same tuff, torn by the action of the sea from the shore-line of reefs. These pebble beds are in fact the shore-line equivalents of the Pozzolana sand and rounded lapilli of the Starza, which, where now seen in section, were deposited farther from the shore.

Subsequent to the erosion of these ancient tuff reefs, and the deposition around them of conglomerates, gravels, and finer materials, a vent opened at the site of Monte Olibano, and probably at a point now traversed by the strada S. Gennaro. From this mouth issued several trachyte lava streams, one of which, on account of its great viscidity, stopped a short distance from its point of issue, piling itself up and accumulating in the place where we now see it cut into chiefly by man's hand, and forming great irregular cliffs in the different stone quarries on the Pozzuoli road.

Before this lava flowed out, a great quantity of the fused rock was ejected by the violence of the explosions in a fragmentary state as scoriæ and pieces of scoriaceous trachyte, which falling formed very irregular strata often several metres thick. The contact of these pieces of hot rock with the subjacent pozzolana and tuff has produced in most places the usual characteristic red coloration which indicates that the land had then risen very considerably, for had the hot scoriæ fallen into the water they would have been cooled before they reached the bottom, and could not then have produced the characteristic coloration.

At the lowest point where scoriæ are in contact with older deposits, and close to the Pozzuoli road, the reddening is absent, and therefore we must conclude that although elevation had gone on it had not yet attained that level.

Probably there were several eruptions from Monte Olibano, though it is difficult to determine how many, for between the bands of trachytic scoriæ beds of re-sorted tuff occur which probably required a certain time to be deposited.

Some traces of the crater formed during the principal explosions are to be seen to the right of the upper road going to S. Gennaro and Pozzuoli and facing the entrance to the *Fondo Sarno.* To the left we see the trachyte in the form of a gigantic mamelon over the side of the vent, and from which is prolonged the short, dumpy lava stream that probably flowed over the lower edge of the crater towards the sea.

The mass of trachyte which in part constitutes the inner south declivity of the actual crater of the Solfatara is a trachyte lava which flowed to the N. or N.W. at a date corresponding to the first eruptions of the volcano of Monte Olibano, and the masses and altered breccias, &c., which now form the steep boundaries of the solfatara crater and posterior to the trachyte are due to later eruptions of Monte Olibano and the actual Solfatara. It was also from here that issued those streams seen in the cliff behind the Bath establishment of Subveni Homini, which are, therefore, probably more ancient than the trachyte of the Cava Regia, Mura, &c.

The mass of trachyte of the Solfatara crater wall might also be a dyke, but it seems impossible for it to have so nearly reached the surface without overflowing. The actual crater of the Solfatara was produced by an explosion at a posterior epoch, the material from which accumulated in great deposits upon all the anterior formation, and considerably changed the preceding configuration of the surface.

Practical results.—The sewer, on quitting the chocolate-coloured pozzolana and lapilli of Bagnoli near the Stabil' Patamia, will pass through the boulder and pebble deposit of unimportant thickness, after which the compact yellow tuff will be traversed for some considerable distance. Thence it will again pass into the boulder and pebble formation and gradually from coarser to finer pozzolana and sand of different kinds.

For the above-mentioned geological regions it is impossible to determine with precision the internal limits of these various formations, even at a small distance from the road.

Even at the surface, the cliff section from La Pietra to Pozzuoli is one of the most intricate of the Campi Flegræi, itself a most complicated region.

The canal by which the main mass of trachyte of Monte Olibano issued is probably situated beneath the highest eminence of the lava, that is, at Cariati (see fig. 3). If such is the case, and if the column of cooled lava is not of very great dimensions, the tunnel as projected would pass a little to the south; but if my calculations be erroneous or if there be any marked irregularities, it may be requisite to perforate the compact trachyte for some indeterminable distance.

I do not believe that the sewer will meet with the scoriæ beds which were found near the road in the Cumana Railway tunnel, after passing farther into the hill where, from the direction of the dip, these strata would be found at a higher level. But even here an exception might occur in the case that the inner declivity of the old filled-up crater of Monte Olibano extended far seawards. At any rate, it is to be hoped that this scoriæ deposit will not be met with, because, with its structure full of interstices between irregular-shaped fragments, the exit of hot and poisonous vapour would occur with great ease.

2. *Temperature of the ground to be traversed.*—An atmosphere, the temperature of which exceeds the normal blood heat of man, is a condition of the greatest importance in the employment of human labour. This normal temperature of the body can only be maintained by the evaporation of the perspiration, and the evaporation is in inverse proportion to the amount of aqueous saturation of the atmosphere. Man is capable of enduring for a relatively long time, in a dry atmosphere, a temperature equal to that of boiling water; but if the air be saturated with moisture, the individual would be immediately subject to grave injury.

It is therefore necessary not only to examine the temperature but also that of the relative saturation.

Studying the ground from this point of view, the first fact that presents itself is that at the *Bocca Grande* of the Solfatara, a very abundant escape of gas composed chiefly of water-vapour takes place, and presents at the point of its exit a temperature of 156° C. (December 12, 1889) which were it pure water-vapour would correspond to a pressure of $5\frac{1}{2}$ atmospheres. We cannot determine at what rate the temperature and pressure of the vapour diminish as we recede from this point of maximum at the Bocca Grande, nor do we know in what proportion the temperature of the ground diminishes as we recede from the centre in a horizontal plain. If we assume empirically a diminution of pressure of gas and temperature of the ground proportional to the distance between two points at which the temperature is known, we may get an idea of that of the tunnel where it approaches nearest to the Solfatara.

In the Cumana Railway tunnel, under Monte Olibano, the working temperature was 60° C. The distance of this tunnel from the Bocca Grande is 860 m. which equals a diminution of 0·11136° per metre; and as the sewer will pass at 740 m. from the same point of maximum temperature, we consequently should find in it a temperature of 73·40°.

In one of my excursions I found a fumarole, about a hundred metres to the S.E. of Cariati, from which was issuing a current of vapour with slight blowing, sufficiently to be sensible at half a metre distant from the opening. With an outside temperature of 15° C. I found the temperature of the issuing vapour 30° C. at the mouth of the fumarole. This fumarole occurs at a much greater height than the level of the sewer, and slightly to the north.

Practical results.—All these facts would indicate that the sewer will have to traverse very hot rocks with abundant humidity, because the bottom level is a very short distance above the drainage level, as indicated by the neighbouring wells to be water at a very high temperature. As the conditions require that the tunnel shall in this neighbourhood be of considerable length without lateral openings, some doubt must be raised in our minds whether, should there be an abundant escape of vapour under pressure, artificial ventilation could render the continuance of the work practicable.

3. *Exhalation of poisonous or deleterious gases or vapours.*—We have seen that by the compacter rocks, and by the interstices of the friable rocks, as the gravelly pozzolana and the trachytic scoriæ, we might encounter exhalations of very high temperature. But these same exhalations might contain not only aqueous vapour, but also other substances.

At the Solfatara the vapour, according to Breislak and many other investigators, contains, besides the aqueous components, much sulphurous acid, ? sulphuretted hydrogen, arsenic sulphides, arseniuretted hydrogen, carbonic acid, and traces of ammonia.

We find these compounds most abundant at the Bocca Grande, and in proportion to the distance therefrom the exhalations gradually lose most of the other compound, the aqueous vapour only remaining.

In studying the region where these exhalations decompose the rocks, we find that it is limited principally to a line directed from N.W. to S.E.; which line, if prolonged S.E. of the crater of the Solfatara and the outer walls on the same side, would pass by Monte Dolce, where a fissure exists in the yellow tuff. At one time it was possible to penetrate into the cleft for some 10 to 15 m. from the Pozzuoli road, and with more limited dimensions even into the mountain. From this cleft there constantly issued hot vapours, and all the surface of the tuff walls was covered by crystals of gypsum, which would seem to indicate that if not at present, at least a short time ago, the vapours contained compounds of sulphur, which becoming oxidised into sulphuric acid had attacked the alkaline and earthy constituents and formed fresh compounds, of which the gypsum has remained in consequence of its feeble solubility. This cleft has lately been filled up and built over in making the tunnel of the Cumana Railway.

Practical results.—Besides the high temperature the exhalations into the workings might not only consist of simple steam, but may contain different gases or vapours of an irritant or irrespirable nature, which could be got rid of only by powerful ventilation.

Besides this difficulty we know that in the vicinity of the Solfatara these exhalations rapidly decompose every mineral substance, and therefore the walling of the sewer would suffer from the action of the sulphuric acid which would be formed by the oxidation of the sulphur exhalations. This acid, attacking the rocks, would tend to convert the cuniculus into an alum cave. This effect would, however, be to a certain extent mitigated in the lower part by the continuous flow of sewage relatively cold. In proof of this numerous old Roman walls are entirely broken up by such action in sites much farther removed from such an active fumarolic focus.

4. *Thermo-mineral waters.*—The wells that one encounters in this region are mostly situated very near the sea, and offer few facts from which deductions of much value can be drawn. Their water possesses nearly always a temperature exceeding 50° C., and on account of the porosity of the soil they are capable of affording a constant supply when heavily pumped. In the crater of the Solfatara we have a well of thermo-mineral water, the level of the water in which is much above the sea-level. But this, however, probably depends on its being closed in a crater basin rendered impermeable by the deposits of clay due to the decomposition of the trachytic rocks at Pozzuoli. It is known that the subterranean drainage level rises rather rapidly as we recede from the shore, so that at the Montagna Spaccata it attains 13 m. This occurs in formations in part identical and in part resembling those which the sewer must traverse in the region discussed in this paper.

Practical results.—It is not probable that the drainage level of the ground will be as high as that of the sewer. Nevertheless it will not be found much beneath the bottom of the tunnel, and where open-structured rocks are traversed the humidity of the atmosphere will be much augmented.

5. *Change of level.*—The sewer must traverse the most classical region renowned for the clear and unmistakable evidence of the oscillation of level of many metres during the historic period; a phenomenon still in progress.

It is not necessary to record here the studies of so many scientists who have demonstrated that the coast of Pozzuoli and other parts of the gulfs of Naples and Gaeta are sinking at a rate of 7 to 14 mm. every year. In the last dozen years that I have studied this region, I have been able to collect such numerous and important facts as to remove any doubt that the change of level is nearer to 13 to 14 mm. than a minimum of 7 mm.

Many new facts in confirmation of this form of bradyseismic movements observed by me in the last years will be found in the reports of this Committee from 1884 to 1889. Unfortunately no accurate observations to determine the rate of this present lowering have been made, which would have been of great use in many engineering and building questions. Also, it is not only necessary to know whether there be lowering of the ground and at what rate, but also the main interest in the present case would be to know if the progress is uniform each season or each year, and above all if it is uniform for all the Naples region.

Individually, I am inclined to think that change of level has been in great part the cause of the abandonment of Pæstum and other analogously situated localities, as well as of the augmentation of malaria during the Middle Ages in the neighbourhood of Ostia and the Roman marshes near the sea, and also of the diminution of the navigability of the Tiber.

The province and the city of Naples should establish several instruments around the coast, one of which should be attached to one of the columns of the Serapeum, to register the level of the water.

Practical results.—If the lowering of the land-level progresses with a uniform rate along the whole length of the sewer this great work can serve for many years, in fact until the bottom of the sewer is considerably beneath the sea-level. But if the sinking is not uniform along its whole course, but greater at one point than another, it might soon become useless on account of the diminished and variable fall at different parts of it.

Conclusion.[1]—In short, we find that the maximum difficulty in the execution of this work is undoubtedly the high temperature of the rocks to be traversed for such a distance without ventilation shafts. Besides these the other obstacles to the work are of no small moment. At any rate this will be a most daring attempt of human skill and enterprise in penetrating into the very bowels of an active volcano.

Fourth and final Report of the Committee, consisting of Mr. R. ETHERIDGE, Dr. H. WOODWARD, *and* Mr. A. BELL (*Secretary*), *appointed for the purpose of reporting upon the 'Manure' Gravels of Wexford.* (*Drawn up by* Mr. A. BELL.)

Wexford and Ballybrack.

The transference of the collections of the Irish Geological Survey to the new Museum of Science and Art, Dublin, has brought to light the greater part of the species recorded by Capt. James ('Journ. Dub. Geol. Soc.' vol. iii.) from the Wexford deposits. A few are yet wanting, and others are preserved in the Museum of Practical Geology, London.

After careful examination I am still of the same opinion—that some were obtained from the marls and not from the gravels. Eliminating these, the following added to my previous list (No. 1) give a fairly complete catalogue of the fauna of the Wexford gravels:—

Aporrhais pes pelecani ?
Fusus rostratus (F. crispus of previous writers).
„ gracilis.
„ islandicus.
„ propinquus.
„ Sabini.
Lacuna divaricata.
„ puteolus.
Melampus pyramidalis.
Mitra — (cornea ?).
Natica affinis.
„ catena.
Nassa reticosa.
„ (semistriata ?)
Pleurotoma exarata.
„ harpularia.
„ nobilis.
„ lævis (n. sp.).
Scalaria Trevelyana.
„ greenlandica.
Trichotropis borealis ?
Trophon Barvicensis.
„ latericeus.
Anomia ephippium.
Artemis exoleta.
Corbula nucleus.
Cytherea Chione.
Leda pernula.
„ pusio ?
Lutraria elliptica.
Mactra solida.
Nucula nucleus.
„ proxima ?
Pecten tigrinus.
„ varius.
Pectunculus pilosus.
Pholas crispata.
Saxicava rugosa.
Tapes virgineus.
Venus fasciata.
Yoldia hyperborea ?

[1] Engineering suggestions have been excluded here, but may be found in the translation published in the *Bol. del R. Com. Geol. It.* 1890, Nos. 1, 2.

A few of the species mentioned by Capt. James, such as Leda pusio, Nucula proxima, Nassa semistriata, and the Mitra, I have not seen. The Leda oblongoides is merely the hinge fragment of a small Yoldia, probably Y. hyperborea. The most interesting find is the crag shell, Nassa reticosa, confirming my suggestion that the Wexford gravels are an extension of the pliocene deposit at St. Erth, Cornwall.

The combined lists give about ninety species as found in the gravels, twenty-nine no longer being represented in British waters, seventeen of them occurring in the Scandinavian Seas, seven Mediterranean, and five extinct.

From Ballybrack I have to add to my previous list Murex erinaceus, a pecten new to the northern fauna, Pecten glaber, and portions of the common lobster (Homarus vulgaris).

Ballybrack to Skerries.

The lower boulder clay or limestone drift is essentially non-fossiliferous, and thus differs materially from the more recent so-called lower boulder clays of North Wales, Cheshire, and Lancashire. Present in Ballybrack Bay, it has its strongest development, so far as regards the coastline, between Howth and the extreme point of Skerries, considerable masses still existing in the outlying Lambay and Shennick Islands.

The shelly gravels on Howth and the Wicklow mountains do not offer much for comment, all the species except two still inhabiting the adjacent seas. The mountain gravels yield few species, and these are all much broken.

Astarte compressa.	Ostrea edulis.
„ elliptica.	Pecten.
„ sulcata.	Pholas crispata.
Cardium echinatum.	Venus casina.
„ edule.	„ striatula.
Cyprina islandica.	(Artemis) lincta.
Lutraria elliptica.	Tellina?
Mactra stultorum.	Trophon muricatus.
Mya truncata.	Turritella terebra.

The Howth shells vary a little in the greater number of gastropods, and are probably of more recent origin, co-equal to the marls in Rosslare Bay, Wexford, and the gravelly sands and marls on either side of Bray Head (*vide* Second Report). Combining the list of Dr. Scouler, Canon Grainger, and other workers, the Howth fauna comprises:

Buccinum undatum.	Cardium echinatum.
Fusus antiquus.	„ edule.
„ gracilis.	Cyprina islandica.
(? islandicus).	Leda pernula.
Littorina littorea.	Mactra elliptica.
„ obtusata.	Mya truncata.
Patella vulgata.	Ostrea edulis.
Pleurotoma turricula.	Pecten opercularis.
Turritella terebra.	„ varius.
Astarte borealis.	Pholas crispata.
„ sulcata.	Tellina balthica.

Balbriggan Bay.

This locality offers some interesting sections; resting upon and in hollows of the bed rocks there occur fragmentary patches of clayey soil mixed with seams of fine gravel, larger rocks, and exposures of limestone drift. Whether all these drifts here and those of Down and Antrim are of the same age as that at Skerries Point and Killiney Bay is questionable; their components are nearly alike, but it may be noticed that in the limestone drift proper the rocks are mostly angular, and much glaciated. In the north of Ireland especially these rocks are very much rolled, and have lost most of the striæ and other indications of ice action, and from this it may be inferred that one is the product of land ice, and the other of water. This inference is strengthened by the presence of broken shells of Cyprina, in the midst of the rocks in Balbriggan Bay, the true limestone drifts being absolutely unfossiliferous, as mentioned already. Amongst the gravels small patches of shelly matter are not uncommon at the lower part of the cliffs, much comminuted, and hardly identifiable. The fauna is peculiar, yielding the boreal forms.

Astarte borealis.
Leda abyssicola.
„ arctica.
„ pernula.
Saxicava norvegica.
Tellina calcarea.
Columbella rosacea.

RECENT BRITISH.

Astarte compressa.
„ sulcata.
Cardium echinatum.
Isocardia cor.
Leda minuta.
Lutraria elliptica.
Nucula nucleus.
Tellina balthica.
Dentalium entalis.
Littorina littorea.
„ obtusata.
Turritella terebra.

Unlike the boreal species found in the clays about Belfast and Carrickfergus, the pelecypoda are all in single valves, and evidently not in their original habitat.

The clay is best seen on the shore about a mile and a half north of Skerries. The richest part, from whence Canon Grainger got many of the rarest species in the above list, is now covered up by masonry.

Beyond the lighthouse the foreshore slates, schists, and other Ordovician rocks are capped more or less by the usual clay, with striated boulders and local débris. Traces of a raised beach are visible in the banks near the town, and in a low cliff at the bend a little farther on. Other portions of this raised beach are present at the other side of the bay, by Lowther Lodge. The fauna is strictly local, and in the same condition as the more recent shells found upon the shore.

Where the cliff is at its lowest, marking an old line of drainage, it is covered by apparently the remnants of an old sand dune, full of landshells of few species, and an abundance of littoral shells. Certain changes have occurred in the distribution of these, the periwinkles of the shore differing in proportion to those in the sands. Thus, of twenty examples, picked at random off the rocks and seaweed, seventeen were Littorina rudis, two L. littorea, and one L. obtusata. In the sands, on the contrary, the last two species abound, and L. rudis is almost, if not quite, absent.

Raised Beach Fossils in Balbriggan Bay.

Aporrhais pes pelecani.
Buccinum undatum.
Cypræa europæa.
Dentalium entalis.
Fusus antiquus.
Helcion pellucidum.
Littorina littorea.
„ obtusata.
„ rudis.
Murex erinaceus.
Nassa pygmæa.
„ reticulata.

Patella vulgata
(var) athletica.
Purpura lapillus.
Rissoa parva.
Trochus cinerarius.
„ umbilicatus.
„ zizyphinus.
Turritella terebra.
Astarte sulcata.
Cardium echinatum.
„ edule.
Corbula nucleus.
Cyprina islandica.
Lutraria elliptica.
Mytilus edulis.
Pecten maximus.
Tapes decussata.
Tellina balthica.
Venus striatula.

Bulimus acutus.
Helix concinna.
„ ericetorum.
„ hispida.
„ rufescens.
„ virgata.
Pupa sp.

Balanus porcatus.

Beyond the sands, where the ground rises, a band of consolidated gravel, with a few shells, chiefly patella, occurs on the face of the cliff, the northern point of the bay; the clay, with striated boulders and local débris, resting upon metamorphosed schists.

Boulder Clays of the North-East.

Under this name are comprised a series of gravels, fine clays, and clays replete with rocks and boulders exhibiting signs of glacial action. The majority of these, unlike those in the limestone drifts further south, are much rolled and water-worn. In a section now obscured by talus, on the coast road from Larne to Glenarm, near Ballyrudder, the lowest beds consist of current bedded shelly gravels, yielding a fauna containing a percentage of nearly 35 per cent. of exotic forms, a larger percentage than occurs in any other Irish post-tertiary deposit. Mr. Stewart records ('Proc. Belfast Nat. Field Club,' Appendix, 1879–80) the following species. The exotic forms are distinguished by the mark *; those on Canon Grainger's authority †:—

Buccinum undatum.
* „ greenlandicum.
Chiton marmoreus.
Lacuna divaricata.
†Littorina littoralis.
† „ obtusata.
† „ rudis.
Nassa incrassata.
*Natica affinis.
„ Montacuti.
*Pleurotoma decussata.
* „ exarata.
* „ pyramidalis.
„ turricula.
Puncturella Noachina.
†Purpura lapillus.
†Trochus cinerarius.
*Trophon clathratus.
„ truncatus.
*Turritella erosa.
Turritella terebra.
*Rhynchonella psittacea.
Anomia ephippium.
Astarte compressa.
„ elliptica.
†Cyprina islandica.
Leda minuta.
† „ pernula.
„ pygmæa.
Lucina borealis.
Mactra subtruncata.
† „ elliptica.
Modiolaria marmorata.
†Mya truncata.
Mytilus edulis.
*Pholas parva.
Saxicava arctica.
Tellina balthica.
* „ calcarea.

These gravels are succeeded by sands and clean clays, or with seams of fine gravel, passing upwards into a clay containing much chalk, and lastly into a very stiff, unfossiliferous, unstratified clay, full of rocks and glaciated stones.

The fine clay is well seen, not only here but in numerous places in this area. It is, however, nowhere rich in fossils; with few exceptions single examples are the rule. Some of the bivalves, more especially the Ledas, are in pairs, and preserve their epidermis; and from the condition of these, and such other species as I have seen or obtained from Ballyrudder, Woodburn Glen, and about Belfast, I believe the shells to be in their original place, and not removed from elsewhere, and that neither the gravels, fine clay, nor the unstratified clay above, come under the term boulder clay, in the sense of the Scottish till, but to be the production, in its earlier stages, of ordinary marine action, and in its later of water-borne bergs and ice floes.

About fifty species have been recorded, chiefly obtained by Messrs. Bryce and Hyndman, and Stewart, and from an examination of their collections in the Belfast Museum, and the fact that the percentage of exotic species is only about 11 per cent., I am of opinion that the association of the clay at Ballyrudder with the underneath gravels is simply incidental, the two deposits having only a stratigraphical relation to each other.

Fossils of the Boulder Clays.

Aporrhais pes pelecani.
Buccinum undatum.
Cypræa europæa.
Emarginula fissura.
Fusus antiquus.
 ,, contrarius.
 ,, gracilis.
Lacuna pallidula.
Littorina littorea.
Murex erinaceus.
Nassa pygmæa.
 ,, reticulata.
*Natica affinis.
Purpura lapillus.
Trochus tumidus.
*Trophon clathratus.
* ,, Gunneri.
* ,, latericeus.
 ,, truncatus.
Turritella terebra.
Anomia ephippium.
Arca lactea.
 ,, pectunculoides.
*Astarte borealis.
 ,, compressa.
 ,, elliptica.
 ,, sulcata.
Astarte triangularis.
Cardium echinatum.
 ,, edule.
 ,, nodosum.
Leda minuta.
 ,, pernula.
* ,, pygmæa.
Lucina borealis.
Mactra elliptica.
 ,, subtruncata.
 ,, truncata.
Mya truncata.
Mytilus edulis.
Nucula nucleus.
Ostrea edulis.
Pecten maximus.
Pectunculus glycimeris.
Pholas crispata.
Saxicava rugosa.
Scrobicularia piperata.
Tapes aureus.
 ,, decussatus.
Tellina balthica.
* ,, calcarea.
Venus gallina.
 ,, ovata.

The 'Turbot Bank,' Co. Antrim.

This interesting deposit consists of a great submarine bank of sand and gravel extending at a depth of 25–30 fathoms from opposite Island Magee southwards across the entrance of Belfast Bay, the water outside deepening rapidly till, at Larne, bottom is touched at 112 fathoms, and opposite Belfast Lough, between it and Galloway, at 149 fathoms. It is still a matter of uncertainty as to whether the organic remains obtained by Messrs. Hyndman, Warren, and others, in the course of the dredging operations conducted by them and described in the 'Rep. Brit. Ass. Adv. Sc. 1857–59,' should be regarded as recent or fossil. Of nearly 200 species of shells recorded, a very few were found living, and of the remainder it is hard to discriminate between those which are certainly only found living in boreal waters at the present day, and those associated with them here, their condition and general appearance being so much alike. Furthermore, at least 35 of the species are only known in the N. E. Irish seas from this one locality, and 85 (excluding those to be presently quoted) have no representatives in any of the estuarine clays or other fossiliferous deposits of the mainland.

Writing to me some twenty-five years back, when sending a parcel of his dredgings, Mr. Waller expressed the opinion that many of the shells were fossil, and not recent; and having had since then, through the kindness of Mr. Stewart, the opportunity of working out a quantity of Mr. Hyndman's material, and inspecting his collection in the Belfast Museum, I have had unusual facilities for examination of the débris, and have arrived at the same conclusion.

Polyzoa are plentiful, both free and adnate, a circumstance unequalled elsewhere in Ireland in any post-tertiary deposit, and are now under examination. Fish, Crustacea, and Corals are rare, but Balani, Annelids, and Echinoderms fairly plentiful. Amongst the latter occur Echinocyamus pusillus, Echinus esculentus, E. miliaris, E. Flemingii, and another species, Amphidetus cordatus, &c. A list will be published when the species are fully determined.

In addition to the boreal species given in the following list there are others, such as Loripes lacteus, E. rosea, Trochus striatus, Rissoa striatula, and Adeorbis subcarinata, of a southern origin, not known elsewhere in the north-east seas. The latter was not unfrequent in the Portrush beds, and the presence of Trochus Duminyi and other forms, more or less southern in origin, in Bundoran Bay may indicate an extension northwards of southern influences, of which the Bundoran fauna is a reminiscence.

The undermentioned boreal species are certainly fossil, whatever may be the case in respect to the other mollusca.

Acirsa borealis.
Buccinum cyaneum.
Cerithium metula.
Cerithiopsis costulata.
,, pulchella.
Columbella Holböllii (rosacea).
Margarita cinerea.
,, greenlandicus.
Molleria costulata.
Natica affinis.
,, greenlandica.
,, islandica.
Pleurotoma Trevelyana.
Puncturella Noachina.
Trophon clathratus.

In addition to the species already recorded from the bank in the Reports of the Belfast Dredging Committee 1857–69 I find Anomia patelliformis, Mytilus phaseolinus, Thracia distorta, two or three Chitons, Buccinum undatum, also Fusus islandicus and Terebratulina caput-serpentis, and the dorsal valve of an allied species which does not seem to have been described, and a Trochus near to T. Montacuti which may be foreign.

I also find a small West Indian shell, Planaxis lineata, not uncommon elsewhere on the Irish coast, a Tellina, Sportella carnaria, also W. Indian, and an exotic Cylichna. The occurrence of so many exotic shells as are recorded from the western side of the Irish Sea is a matter deserving further investigation. The co-existence of northern and southern forms in the same waters is amply proved by the taking in the same haul, in 348 fathoms off the south of Ireland, such extreme forms as Fusus islandicus and Cassidaria tyrrhena, both fine and living. Their occurrence therefore together in an old deposit does not imply that either the northern or southern species must have been transported thither.

The Estuarine Deposits

of the north-east of Ireland occupy a considerable area, inland, of the margins of the loughs and estuaries indenting the coast. Few deposits are so rich in species, or so well preserved. Neither in Scotland nor England is there any one that can be compared with them in this respect.

The building of the various docks at Belfast has enabled Canon Grainger, Mr. S. A. Steward, and Mr. R. Lloyd Præger to collect largely, and, in doing so, to examine the nature and stratification of the various members of the group. In hardly two sections are the features alike. In Spencer basin Mr. Stewart found a thickness of 20 feet of clay, the upper portion being crowded with littoral shells, the middle with Thracia and species pertaining to a fauna living in from five to ten fathoms, and at the base, or lower portion, a zone of scrobicularia. Mr. Præger[1] in the Alexandra Dock found sand, blue clay, peat, sand, re-assorted boulder clay, and boulder clay with striated rocks. At Magheramorne, on the left bank of Larne Lough, the clay is above the surface, and may have been brought up by the pressure and thrust of the adjacent railway embankment. Here the zones of life are less marked, and the several species are more grouped than seems the case elsewhere. The fauna in different localities varies much—thus at Belfast, Thracia convexa, Cardium echinatum, Lucinopsis undata abound. At Magheramorne these are rare, or absent, and Modiola modiolus, Lima hians, and Tapes virginea are in quantity, and these are very scarce at Belfast. Polyzoans are rare; I know only one obtained on a pecten, at Magheramorne, by myself. The microzoa have been taken in hand by Mr. Joseph Wright, F.G.S., Belfast, who is still at work upon them. In thickness the clays are very inconstant, depending apparently more upon the breadth of the estuary than upon their proximity to the water line. Thus in the Spencer basin they have been found 20 feet thick, and at the Curran Larne only 3 feet, the one estuary being much narrower than the other.

Considering the richness of the fauna, it is singular that some of the molluscs reached an enormous size, and the paucity of the gastropodous mollusca is striking. Of the hundreds of bivalves that have passed through my hands I do not remember one that had been perforated. It may be from this cause that the bivalves grew so large. From Magheramorne I have taken oysters 5 inches across, Tapes virgineus 3 inches, and others in proportion. The Pholades (P. crispata) are the largest known, running up to 5 inches by $2\frac{1}{2}$. These are found only in the Belfast excavations. Assiduously as the beds have been searched, remains other than molluscs and microzoa are rare, most of them being single specimens, except Echinus miliaris, which is not uncommon at Belfast.

The shells in the lists of the mollusca of the estuarine clays of the north-east of Ireland have been obtained chiefly from the estuaries of Belfast and Larne, at Magheramorne. Strangford Lough, Limavady, and

[1] *Proc. Belfast Nat. Field Club*, 1888.

some other similar deposits have still to be examined. So far as yet known, although microzoa are plentiful, shells and other organisms are scarce in comparison with the number of localities. Species marked † occur mostly in unequal proportions, both at Magheramorne and Belfast; those marked * at Magheramorne only, the remainder only at Belfast. The Magheramorne list, and all those in italics, are on my own responsibility, and I have been able to verify most of the remainder through the courtesy of Mr. Stewart.

Mollusca of the Estuarine Clays of N.E. Ireland.

Aclis supranitida.
Aporrhais pes pelecani.
†Buccinum undatum.
†Cæcum glabrum.
Capulus hungaricus.
†Cerithium reticulatum.
†Cyclostrema nitens.
* „ „ var. Alderi.
†Cypræa europæa.
Eulima bilineata.
Fissurella græca.
Fusus antiquus.
„ gracilis.
Helcion pellucidum.
*Homalogyra atomus.
* „ rota.
†Hydrobia ulvæ.
†Lacuna crassior.
„ divaricata.
† „ pallidula.
* „ puteolus.
†Littorina littorea.
„ *neritoides.*
† „ obtusata.
† „ „ var. æstuarii.
† „ rudis.
† „ „ var. tenebrosa.
†Murex erinaceus.
†Nassa *nitida.*
„ pygmæa.
„ reticulata.
Natica Alderi.
„ catena.
„ *greenlandica.*
†Odostomia acuta.
* „ *eulimoides.*
„ interstincta.
* „ minima.
† „ pallida.
* „ plicata.
* „ rissoides.
(Chemnitzia) indistincta.
† „ lactea.
†Patella vulgata.
Pleurotoma brachystoma.
„ costata.
† „ rufa.
„ septangularis.
„ turricula.
(Defrancia) gracilis.

†Purpura lapillus.
*Rissoa albella.
* „ calathus.
* „ cimicoides.
* „ costulata.
„ inconspicua.
† „ membranacea.
* „ punctura.
* „ parva.
* „ reticulata.
* „ Sarsii.
† „ striata.
* „ „ var. arctica.
„ violacea.
„ vitrea.
Scalaria Turtonis.
*Skenea planorbis.
Tectura virginea.
†Trochus cinerarius.
† „ magus.
„ umbilicatus.
†Turritella terebra.

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†Acera bullata.
Actæon tornatilis.
†Amphisphyra hyalinus.
Cylichna cylindracea.
„ nitidula.
Melampus bidentatus.
Philine aperta.
„ scabra.
Scaphander lignarius.
*Utriculus mammillatus.
† „ obtusus.

LAND SHELLS.

Helix nemoralis.
(Zonites) crystallinus.
* „ nitidulus.

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†Anomia ephippium.
„ „ var. aculeata.
† „ patelliformis.
„ „ var. striata.
Arca tetragona.
Axinus flexuosus.
†Cardium echinatum.
† „ edule.

†Cardium exiguum.
† „ nodosum.
„ *norvegicum.*
Ceratisolen *legumen.*
†Corbula nucleus.
*Crenella marmorata.
†Cyamium minutum.
Cyprina islandica.
Gastrochæna dubia.
*Kellia suborbicularis.
Leda minuta.
†Lima hians.
†Lucina borealis.
†Lucinopsis undata.
Lutraria elliptica.
„ oblonga.
Mactra elliptica.
„ *solida.*
† „ subtruncata.
† „ truncata.
Modiolaria marmorata.
†Montacuta bidentata.
„ ferruginosa.
Mya arenaria.
„ truncata.
†Mytilus adriaticus.
† „ edulis.
† „ modiolus.
†Nucula nucleus.
* „ *sulcata.*
†Ostrea edulis.
†Panopœa plicata.
†Pecten opercularis.
† „ maximus.
„ pusio.
† „ varius.
*Pectunculus glycimeris.
Pholas candida.
„ crispata.
„ dactylus.
Psammobia ferroensis.
„ vespertina.
*Saxicava rugosa.
„ „ var. arctica.
Scrobicularia piperata.
†Solecurtus antiquatus.
Solen ensis.
„ pellucida.
† „ vagina.
*Sphænia Binghami.
†Syndosmya alba.
„ *tenuis.*
†Tapes aureus.
† „ „ var. ovata.
† „ decussatus.
„ pullastra.
† „ virgineus.
†Tellina balthica.
„ *fabula.*
„ squalida.
„ tenuis.
Teredo norvegica.
Thracia convexa.
„ papyracea.
„ „ var. villosiuscula.
„ pubescens.
*Venus casina.
† „ fasciata.
† „ gallina.
* „ ovata.
(Artemis) exoleta.
„ lincta.

Raised Beaches. County Antrim and Down.

Resting upon the estuarine clays thick masses of gravel yielding shells, and in places flint flakes and other rudely fashioned implements, occur in many localities, more especially about Carrickfergus and the Curran, Larne. Midway between they may be seen overlying the chalk, and other rocks by the railway station.[1] Here I obtained a number of species—the bivalves in pairs and *in situ*, similar to those seen in a section lately opened at the Curran, under the auspices of the Belfast Nat. Field Club to determine the greatest depth at which flint implements occurred. This was found to be 19 feet from the surface immediately above the estuarine clay, and gives a valuable datum line as to the earliest known presence of man in Ireland. The suggestion that these gravels are the equivalents of the 25-foot raised beaches of Scotland is not borne out by the fauna, and I have come to the conclusion that they are much more recent.

The various raised beaches of North-East Ireland have a very equal fauna, the following list being compiled from the writings of Canon Grainger, the Proceedings of the Belfast Field Club, and my own findings.

[1] Magheramorne.

Aporrhais pes pelecani.
Buccinum undatum.
Cerithium reticulatum.
Fusus antiquus.
Helcion pellucidum.
Hydrobia ulvæ.
Littorina littorea.
„ rudis.
„ obtusata.
Nassa incrassata.
„ pygmæa.
„ reticulata.
Patella vulgata.
Pleurotoma rufa.
Purpura lapillus.
Rissoa membranacea.
Trochus cinerarius.
„ magus.
„ zizyphinus.
Turritella terebra.
Anomia ephippium.
Artemis exoleta.
Cardium edule.
Corbula nucleus.
Cyprina islandica.
Kellia suborbicularis.
Lucina borealis.
Mactra subtruncata.
Modiola modiolus.
Mya truncata.
Ostrea edulis.
Pecten maximus.
„ opercularis.
„ varius.
Saxicava rugosa.
Tapes aureus.
„ decussatus.
„ pullastra.
Tellina balthica.
„ tenuis.
Venus gallina.

If these gravels are of the same age as the one in Balbriggan Bay, the conditions under which they were accumulated were very different, as in them most of the shells are perfect and *in situ*; while at Balbriggan they are all broken and have drifted into their present position.

Waterford Haven.

Brief reference may be made to the estuarine flats in Tramore Bay, County Waterford, which fall within the human epoch, and abound in the shells of the common cockle. These flats have an elevation of 8 to 10 feet above high water, the shell bands ranging from 2 to 12 inches in thickness. In one of these Major Austen[1] saw a human skeleton evidently contemporaneous, as the shells were lying both above and below it. From the notes kindly sent me by Mr. E. Garnett, of Newtown, these beds must have been still more elevated, as they underlie at one extremity a thick bed of dark turf-like mould, containing many stumps and roots, mostly of birch and oak trees. The late Professor E. T. Hardman told me that he had seen other shells besides the cockle, such as Aporrhais, Littorina, Turritella, &c., but had not time to examine the bed thoroughly. They must be rare, as Mr. Garnett writes that he could only find the one species.

A deposit of the same age as the above may be that known as Clay Castle, Youghal, an eminence facing the sea, built up of a gravelly sandy clay, with shells of the ordinary type such as the ordinary whelk, limpet, mussel, and cockle, with a few others.

Portrush, Co. Antrim.

The deposit here consists—or rather did so, since the building of a road round the small bay in which it occurred has blotted it out of sight—of a bed of sand formed in and about the hollows of the rocks some ten feet above high-water. Originally discovered by the late Mr. James Smith, of Jordanhill, its fossils were referred to in a list given in Port-

[1] *Proc. Geol. Soc.*, Lond. vol. ii. p. 300.

lock's 'Geology of Londonderry,' &c. From material kindly forwarded to me by Messrs. Gray and R. G. Symes, F.G.S., I have been able to verify nearly all the species mentioned, and to add others. The most abundant forms are Patella, Helcion, Purpura, and Rissoa, and the whole series suggests their habitat to have been some rocks close by, covered with laminaria. Few things except shells are present, crab-claws, two or three echinoderms, a coral (*Caryophyllia clavus*), and three polyzoans exhausting the list. The synonomy of Portlock's list is in part obsolete, and the present one is brought up to date, Portlock's names, where different, being given in brackets. All the species are still present in the Irish Seas.

Adeorbis subcarinata.
Aporrhais pes pelecani.
Barleeia rubra (Turbo unifasciata).
Buccinum undatum (*fide* Canon Grainger).
Cerithiopsis tubercularis.
Cerithium reticulatum.
(Triforis) adversum (Murex a.).
,, perversum.
Chiton fascicularis.
,, marmoreus.
Cypræa europæa.
Emarginula fissura.
Eulima polita.
Fissurella græca.
Helcion pellucidum.
,, ,, (var. lævis).
Hydrobia ulvæ.
Lacuna divaricata (Turbo canalis).
,, pallidula.
,, puteolus.
Littorina littorea.
,, neritoides.
,, obtusata.
,, rudis.
,, ,, (var.) jugosa.
,, retusus.
Murex erinaceus.
Nassa incrassata (Buccinum macula).
,, nitida.
,, pygmæa (Buccinum minimum).
,, reticulata.
Natica Alderi.
,, catena (N. glaucina).
,, Montagui.
Odostoma acuta.
,, excavata.
,, plicata.
,, spiralis.
,, turrita.
,, unidentata.
(Chemnitzia) lactea.
Patella vulgata.
,, ,, var. cerulea.
Phasianella pullus (Turbo p.).
Pleurotoma costata.
,, rufa.
,, septangularis (Fusus s.)
Pleurotoma striolata.
(Defrancia) linearis (Fusus l.).
,, purpurea.
,, reticulata.
Puncturella Noachina.
Purpura lapillus.
Rissoa albella.
,, cancellata (Cingula cimex).
,, cingillus (as Turbo c. and R. fallax, n. sp.).
,, costata.
,, costulata.
,, inconspicua.
,, parva (Cingula alba).
,, ,, (var.) interrupta.
,, punctura.
,, reticulata.
,, semistriata.
,, striata (Pyramis s. and P. discors).
,, Zetlandica.
Scalaria clathratula.
,, Trevelyana.
Tectura virginea (Patella v.).
Trochus cinerarius.
,, magus.
,, tumidus.
,, umbilicatus.
,, zizyphinus.
Turritella terebra.
Trophon muricatus.
Utriculus truncatulus.

Terebratula cranium? (*fide* Portlock).

Anomia ephippium (also A. squamula and A. undulata).
,, striata.
Arca lactea.
,, tetragona (A. papillosa).
Astarte sulcata (Crassina scotica).
,, triangularis (Mactra triangulata).
Cardium edule.
,, exiguum.
,, fasciatum.
,, nodosum.

Cardium norvegicum (C. elongatum).
Circe minima.
Cyprina islandica.
Lasea rubra (Anatina ovalis).
Lima hians.
Lucina borealis.
Mactra elliptica.
„ subtruncata.
„ truncata.
Mya Binghami.
Mytilus edulis (var. incurvata).
Montacuta ferruginosa.
Nucula nucleus (N. margaritacea).
„ tenuis.
Ostrea edulis.
Pandora inæquivalvis.
Pecten opercularis.
„ pusio (P. distortus).
„ varius.
Pectunculus glycimeris.
Saxicava arctica.
Syndosmya tenuis (Tellimya t.).
Tapes pullastra.
Venus casina.
„ fasciata.
„ ovata.
„ gallina.
„ verrucosa.
Venerupis irus.

Land Shells.

Carychium minimum.
Clausilia biplicata.
„ rugosa.
Helix fulva (H. trochilus).
„ pulchella (H. paludosa).
(Zonites) crystallinus.
Pupa pygmæa.
„ Venetzii.
Zua lubrica.

The few polyzoa are Cellaria fistulosa, Cellepora pumicosa, and Lepralia ventricosa. Caryophyllia clava is a rare coral only found at Portrush.

The foregoing references embrace all the horizons and most if not all of the fossiliferous post-tertiary deposits of the eastern side of Ireland, and the lists of fossils are as complete as I have been able to make them.

Passing them in review, and omitting species still living in the Irish Seas, a not inconsiderable list of 47 species calls for some notice as to the means whereby this fauna or rather the remains of several came into this area and on this side of the Irish Sea since not more than 10 or 12 occur on the English side. Looking over the appended synopsis of these exotic shells, 29 are found in the Wexford gravels, including 5 species whose habitat is unknown. All are probably extinct, and 7 species now live only in the Mediterranean Seas. With these are associated 17 of boreal or Arctic origin. In the next stage at Ballybrack the southern fauna falls to 3 and the northern to 5. This may be due however to the very limited area of ground remaining for research. At Ballyrudder, in the gravels, all are northern as they are in the glacial N.E. clays, which latter are probably the equivalents of the Clydian deposits, Bute, and similar deposits in West Scotland, the fauna being almost the same, so far as 6 out of the 7 Irish species are concerned. From the presence of Leda arctica and abyssicola in the Balbriggan bed, it might be placed on the same level as the underlying and older glacial clays of Scotland yielding the most arctic of Scottish faunas; but this is as yet uncertain, as the condition and preservation of the respective faunas and the nature of the matrix they are contained in are entirely different.

Of the Turbot Bank nothing definite can be said. Similar banks are reported on the Dalkey and Killiney side of Dublin Bay; fauna all dead, but *not* containing any of the boreal species of the Turbot Bank, only such as are found in the Bay at the present time. One species, Columbella Holböllii, not uncommon on the Turbot Bank, links it with Balbriggan on the one hand, and again to the Scottish beds at Lochaber. The estuarine and later deposits offer nothing for discussion, exotic species not finding place in them, the faunas only indicating considerable earth movements, and consequent incoming, outgoing, and shifting of species.

There should be some way of accounting for the disparity of these exotic faunas on different sides of a not over wide sea, and the suggestion I would offer is this. Noticing that the unknown or extinct element is so palpable in Wexford, and that the quasi-Mediterranean or southern influence passes by way of Ballybrack into the Isle of Man, it is evident that if a fauna of similar facies can be found to the south, it is there that we should look for the origin of such faunas as occur in the south-east of Ireland and elsewhere as above referred to. Such a fauna as I have already pointed out occurs at St. Erth in Cornwall, but of a much earlier date. This will account for their extinct and southern forms, but not for the large number of northern species, species to be noted, all of Norwegian and Scandinavian types, and not high Arctic, none of which are present at St. Erth. If any hydrographical map of the area of the Irish Sea is consulted, it will be seen that the greatest depression exists in a line not more than a mile broad, running nearer the Irish coast than the English, the 30-fathom line passing outside the Isle of Man from the Mull of Galloway to St. David's Head, South Wales. Continuing northwards there are two routes available, one opening *viâ* the Sound of Jura, and the line of the Caledonian Canal into the Northern Sea at the Moray Firth, the other by way of the Clyde to the Firth of Forth. Both routes were probably available. The neighbourhood about Fortwilliam, at the entrance of the Canal, is fossiliferous, and when worked as carefully as other Scottish beds have been, should show good results. On the other hand, from the west to the east of Scotland by the Clyde-Forth route and north to Banff, the early glacial clays are replete with species of the same northern or boreal type as occur in Ireland, and in one or other of these directions must the fauna have travelled before the line of depression was fully developed, otherwise it is difficult to imagine either the northern fauna passing southwards or the extinct forms northwards into the Isle of Man within the 30-fathom limit, crossing a depression varying from 93 fathoms off Dublin to 194 off Belfast Lough.

Taking Ballybrack as the next in order, the fauna exhibits southern influences in its Woodia, Pecten, and Mediterranean forms, and is in the opinion of the writer equal in time to the Selsey bed in Sussex, equally southern in its origin and unmodified by northern influences by its position being barred by land from northern or western waters.

The final deepening and opening of the channel round the south of Ireland culminated in the final separation of Ireland from the mainland, and permitted the introduction of West Indian species of Bulla and Oliva jaspidea *viâ* ? the Severn straits, into the Worcester gravels. Going north in the same direction into Cheshire and Lancashire southern influences are still felt in the lower levels, but there is no evidence whatever of the existence in N.-W. Wales, Cheshire, or Lancashire of any marine deposits corresponding to the glacial clays of N.-E. Ireland, or the Scottish clays of Bute, and the shelly gravels at elevations of 800 feet and upwards probably correspond to those at 800 feet to 1,200 feet in the Dublin and Wicklow mountains. If these conclusions are correct the present Irish Sea must have been represented by a comparatively narrow belt of water, and Wales formed a large island separated on its eastern side from England by the line of the Severn Sea, anterior to the deep submersion necessary to carry the shells to such heights, the re-elevation of the land leaving the Irish Sea in its present area.

Exotic Mollusca—Extinct. South European and Boreal.

—	Wexford	Ballybrack	Dublin	Balbriggan	Glacial, N.E. Ireland	Ballyrudder	Turbot bank	Estuarine clays	Raised beaches	Portrush
HABITAT UNKNOWN										
Fusus Menapii	*									
Melampus pyramidalis	*									
Nassa granulata		*								
,, reticosa	*									
Pleurotoma lævis	*									
Nucula Cobboldiæ	*									
SOUTH EUROPEAN										
Cypræa	*									
Fusus rostratus	*									
Mitra (? sp.)	*									
Nassa semistriata	*									
Turritella incrassata	*									
Leda pusio ?	*									
Pecten glaber		*								
Woodia digitaria		*								
Pectunculus pilosus	*									
BOREAL										
Acirsa borealis							*			
Buccinum cyaneum							*			
,, greenlandicum						*				
Cerithiopsis costulata							*			
Columbella Holböllii				*			*			
Fusus islandicus	*									
,, Sabinii	*									
Margarita cinerea							*			
Meyeria pusilla	*									
Molleria costulata							*			
,, greenlandica							*			
Natica affinis	*				*	*	*			
Pleurotoma decussata						*				
,, exarata	*					*				
,, harpularia	*									
,, nobilis	*									
,, pyramidalis	*	*				*				
Purpura incrassata	*									
Scalaria greenlandica	*									
Trophon clathratus	*				*	*	*			
,, ,, (var. Gunneri)					*					
,, craticulatus	*									
,, latericeus	*				*					
Turritella erosa						*				
Astarte borealis	*	*	*	*	*					
Leda abyssicola				*						
,, arctica				*						
,, buccata		*								
,, pernula	*	*	*	*	*	*				
Nucula proxima ?	*									
Tellina calcarea		*		*	*	*				
Yoldia hyperborea										
Rhynchonella psittacea						*				
Number of species	29	8	2	6	7	10	9			

In presenting this, the final report, on the Wexford gravels, &c., I have to acknowledge with pleasure the generous help rendered me by many friends, more especially to Mr. S. A. Stewart, of Belfast, for specimens, material, and kindly help in many ways, as well as to the geological members of the Belfast Naturalists' Field Club generally. To Messrs. Gray and Symes I owe my greatest knowledge of the Portrush deposit, and to Professor V. Ball, Dublin, and E. F. Newton, Esq., F.G.S. (Mus. Prac. Geol. London), facilities in examining Captain James's original collection of Wexford fossils. Amongst those no longer with us, I owe much to Messrs. Edward Waller, W. Hellier Baily, W. W. Walpole, and Dr. Gwyn Jeffreys for specimens and information.

In conclusion, I may venture to say that I have seen and examined all the localities referred to, and verified a large number of the species quoted, even if I have not collected them myself. The virtual extinction of many fossiliferous deposits, as at Ballybrack, Balbriggan, and Portrush, by walling up or road making, is to be deplored. Other localities in the north, I am glad to say, are being worked by R. Lloyd Præger, B.A., and the results will appear in due course in the reports of the Belfast Field Club, in which much valuable information concerning the deposits of N.-E. Ireland may be studied with great advantage.

Eighth Report of the Committee, consisting of Mr. R. ETHERIDGE, Dr. H. WOODWARD, *and* Professor T. RUPERT JONES (*Secretary*), *on the Fossil Phyllopoda of the Palæozoic Rocks.*

§ 1. *Saccocaris.* § 2. *Aristozoe.* § 3. *Estheriæ.*

§ 1. *Saccocaris minor, J. & W.*—On a large piece of the 'Upper Shale (=Daearfawr Shale), west of the Crag known as Craig yr hyddod, Arenig,' North Wales, kindly submitted by Professor T. McKenny Hughes, F.R.S., for examination, are numerous, and at first sight somewhat obscure, impressions of a Bivalved Phyllocarid; together with some body-segments of the same. The rock is 'the top bed of shale tangled among the porphyries of the Mountain Arenig. It is therefore the highest fossiliferous zone of the *Arenig* of Arenig.' The slab, measuring 18 by 10 inches and half-an-inch thick, consists of a hard, dark-coloured, fine-grained flagstone (dark-blue within and weathering dull rusty grey), not argillaceous nor calcareous, made up of minute, fragmentary, crystalline particles. One edge is straight and ragged, and the opposite edge is rounded, as if it had been a part of a large fissile concretion. The slab separates horizontally into two parts, and the counterpart surfaces are covered with the fossil impressions, which are mainly convex on one of the faces, and concave on the other. One larger convex cast (fig. 1) lies almost alone on the rusty weathered back of the piece that bears the concave impressions. These carapaces and abdominal segments are merely dark films, more or less flattened, and squeezed across their length. Some, however, among the numerous individuals, are less distorted by pressure, especially one (fig. 1), which is isolated on a different (outer and broadly rippled) surface of the stone.

The crowded fossils lie mostly oblique to the long axis of the stone, near to each other, often close together, more or less parallel, and generally with the same end in one direction. On the plate at page 2, some of the best preserved specimens have been selected and outlined just as the individuals lie on the stone; sometimes as figs. 1 and 2; 9, 10, 11; and 7, 15, 16, 17, in groups.

These carapace-valves are more or less oval-oblong in outline, but often imperfect, and in nearly all cases modified in shape by lateral pressure.

The largest individual (fig. 1), 40 mm. long and 22 mm. high (broad), having probably its original shape or nearly so, has its upper and lower edges slightly convex and nearly parallel; the upper (dorsal) edge is somewhat more fully curved than the other, especially in the antero-dorsal region. The front end (to the left-hand in the figure) was probably rounded, but is broken; the hinder extremity is obliquely truncate, but bears some indication of an ogee curvature, such as is seen in many *Ceratiocaridæ* and other Phyllocarids. Three abdominal segments (one imperfect) are still attached to this end of the carapace; the first two are about 5 mm. long and the third about 7 mm. They appear to have been originally as deep as the carapace, and each segment at its hollow curve below its convexity and lateral articulation was marked with vertical striæ.

The surface of fig. 1 bears five delicate, longitudinal, gently-curved, sub-parallel lines. These lines are partly raised and partly hollow, as if, having a consistency different from that of the rest of the valve, they have been differently affected by the pressure to which the matrix had been subjected.

Fragments of probably a specimen similar to fig. 1 lie close to it, as shown by fig. 2.

There is a remarkable similarity in outline between fig. 1 here described and the fig. 1 at p. 179 (in our Sixth Report, 1888), 'Report Brit. Assoc.,' 1889, which we determined at pp. 175 and 176 of that Report to be the *Saccocaris major* of Salter. Although the relative size differs very much (110 × 50 mm. and 37 × 22 mm.), and the proportions are also somewhat different (110 × 50 : 101 × 66), we are inclined to refer the two specimens (both of which are from the Cambrian rocks) to the same genus. Probably, if it were not for the broken anterior border in the new form, and the broken posterior margin of *Saccocaris major*, they might have presented a still stronger likeness.

We provisionally regard this form as a new species, and call it SACCOCARIS MINOR, fig. 1, p. 427, and define it as follows:—

Carapace valve sub-oblong, arched above, nearly straight below, elliptically rounded in front, with the acme of curvature probably coincident with the mesial line of the valve; truncate behind, with a slightly projecting and blunt angle at its upper fourth. Surface marked with five longitudinal, slightly-curved, sub-parallel lines, somewhat like the nervures in an insect's wing; one or more of the lines seem to branch backwards. Abdominal segments present (see fig. 2, p. 427), and are of considerable interest as connecting this old form with *Hymenocaris* (see figs. 3, 4, and 5 at p. 179, 'Report Brit. Assoc.,' 1889), and with *Ceratiocaris* and other allies. Some of the caudal spines are obscurely preserved on the slab.

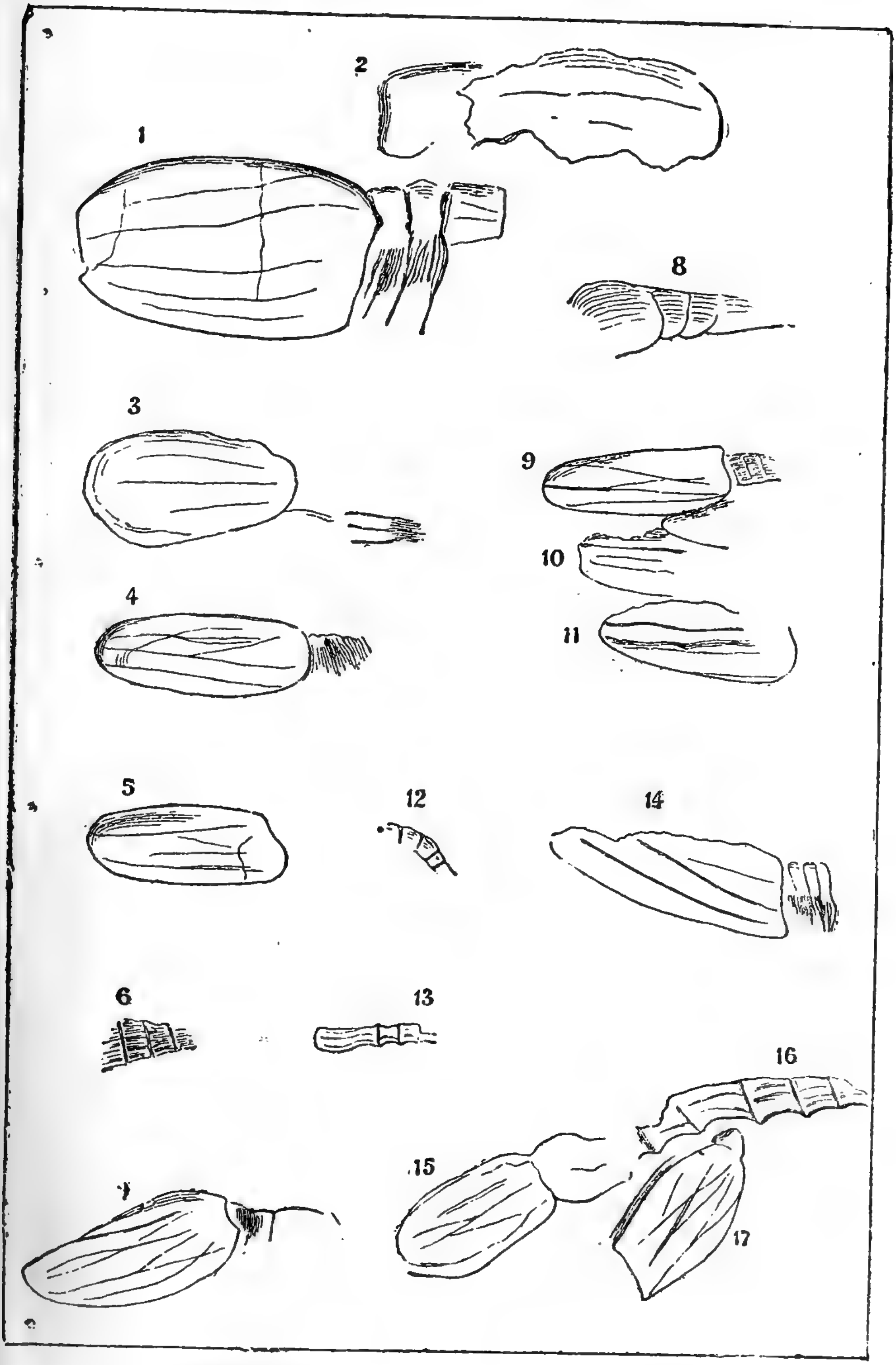
Owing to the pressure that has so greatly affected the other specimens on the two counterpart faces of the split slab, there is considerable variation in the outlines of the individuals, nor do they quite match fig. 1.

Fig. 3 measures 27 × 15 mm.; fig. 4, 27 × 10 mm.; fig. 7, 28 × 11 mm.; fig. 9, 23 × 7 mm.; fig. 11, 25 × 8 mm. Nevertheless some features of fig. 1 are traceable in the majority. Looking at the selected outlines drawn from the slab, we see the rounded front end in figs. 3, 4, 5, 9, 11, 15, 17, and partially in figs. 7, 10, and 14. Figs. 3 and 15 retain some of the proportionate height of fig. 1; but others seem to have become narrower by cross-pressure, but this may have been an original specific feature (although very doubtful). Some trace of the hinder ogee outline is visible in figs. 3, 5, 7, 9, 11, and 15 (sometimes neater than in fig. 1); also in figs. 14 and 17, which are apparently *reversed* valves with the dorsal edge downwards. The superficial longitudinal lines are evident in all the valves; and 4, 5, 7, and 15 show the backward branching, but in fig. 17 the branching veins seem to have a forward direction. Unequal pressure may have modified these appearances. We regard these smaller valves as being most probably immature forms, rather than showing either sexual or specific differences. Abdominal segments are attached to the valves in figs. 3, 4, 7, and 14; and are separate in figs. 6, 8, 12, 13, and 16. In shape, size, and ornament, these differ too much for us to pretend to decide whether they are really all of one kind or not, the modes and degrees of preservation probably making more distinctions than originally existed.

Bearing in mind the gregarious habits of modern Entomostraca, it seems most probable that we have here another illustration of the crowding together of numbers of individuals of *one species* which lived in the same shallow lagoon, a portion of which may have been dried up (as in a modern shore-pool), leaving its inhabitants to perish in the sun and to be covered up with a fresh layer of mud by the next tide. Such a local accumulation of animal matter may have caused a segregation of special mineral matter in the matrix and given rise to the local concretion.

§ 2. *Devonian Aristozoe in France.*—Mons. D. P. Œhlert, of Laval, has lately discovered an *Aristozoe* in the black compact Devonian limestone of Saint Malo, near Angers, Department Maine-et-Loire, and has given an account of this interesting fossil, with good figures, in the 'Bulletin Soc. Géol. France,' ser. 3, vol. xvii. No. 9, December 1889, pp. 768–771, pl. 19, figs. 2, 2*a*, 2*b*. By careful comparison with M. Barrande's figures, he finds that his new fossil corresponds very closely with the Silurian *Aristozoe memoranda*, Barrande, 'Syst. Silur. Bohême,' vol. i., Supplem. p. 480, pl. 34, figs. 43–51, pl. 27, fig. 6, and pl. 32, figs. 16, 17; and therefore he publishes it as '*Aristozoe* aff. *memoranda*, Barr.,' and points out that this is an additional occurrence of a Silurian species, or its scarcely separable representative, in the Devonian system. *Echinocaris* and other allies of the phyllopodous *Aristozoe* are known in the Devonian strata of North America. In Devonshire we have analogous fossils in *Tropidocaris* (?), *Echinocaris*, and *Bactropus* (a caudal segment of *Aristozoe*). See our Seventh Report read at the Newcastle-on-Tyne Meeting, 1889.

M. Œhlert's specimen differs slightly from *A. memoranda*, especially in the cephalic extremity forming a narrower projection than in any of Barrande's figures of that species and in the antero-ventral region being less boldly curved outwards, thus making the ventral outline more nearly subtriangular than in *A. memoranda*. Novák's figure of *A. regina*, Barr., in the 'Sitzungsb. böhm. Gesell. Wissensch.,' 1885, pl. 1, fig. 1, also



Phyllocarida from the Arenig.

closely approaches it in form, but surpasses it greatly in size, and differs somewhat in the curvature of the antero-ventral and posterior margins.

§ 3. *Scotch Carboniferous Estheriæ.*—In our Seventh Report, 1889, reference was made to some fossil Phyllopoda from the Glasgow Coalfield (p. 66). In a memoir on these fossils, communicated by one of us to the Geological Society of Glasgow ('Transact.' vol. ix. part i. 1890), the following determinations have been arrived at:—

(1.) *Estheria Youngii*, sp. nov. (pl. 5, fig. 1), from a shale of the Carboniferous Limestone (Upper Limestone series) at the Arden Quarry, near Thornliebank, four miles S.W. of Glasgow. In the University Museum, Glasgow.

(2.) *Estheria tessellata*, sp. nov. (pl. 5, figs. 2–4), in Cannel-coal, probably from Ayrshire. In the British Museum.

(3.) *Estheria tegulata*, sp. nov. (pl. 5, figs. 5, 6), in Cannel-coal, probably from Airdrie, Lanarkshire. In the University Museum, Glasgow.

(4.) The specimens from Thornliebank and Dalry, formerly referred to *Estheria*, under the name of *E. punctatella*, Jones ('Transact. Geol. Soc. Glasgow,' vol. ii. 1865, p. 71, pl. 1, figs. 5, 5*a*), are now determined to belong to *Posidonomya*.

§ 4. Another palæozoic (Devonian) *Estheria* was noticed by Professor H. Rogers in his 'Geology of Pennsylvania,' vol. vii. part 2 (1858), p. 827, fig. 664, from the 'Cadent older or lower Black Slate,' equivalent to the 'Marcellus Slate of New York.' This *Estheria*, though unnamed, should have been catalogued, with *E. pulex*, Clarke, in our Sixth Report, 'Brit. Assoc. Reports,' 1889, p. 181.

EXPLANATION OF THE FIGURES 1—17.

(All the Outlines are of the Natural Size.)

Fig. 1. *Saccocaris minor*, T.R.J. and H.W. Left valve and three abdominal segments.

Fig. 2. Remains of a similar form lying close by.

Fig. 3. Left valve, broad (or widened ?) in front and narrowed behind, but retaining a trace of the ogee curve; also some signs of abdominal segments.

Fig. 4. Left valve and some abdominal segments.

Fig. 5. Left valve, showing the posterior ogee curve.

Fig. 6. Four abdominal segments, striated lengthwise.

Fig. 7. Left valve, damaged or infolded at the antero-dorsal region; with some abdominal segments. This forms part of a group with figs. 15, 16, and 17.

Fig. 8. An obscure set of abdominal segments.

Figs. 9, 10, and 11. A group of three left valves; fig. 9 has some abdominal segments attached; and both figs. 9 and 11 show the ogee posterior curve.

Figs. 12 and 13. Two specimens of obscure segments, too small apparently for any of the carapaces here outlined, and therefore indicating either younger forms or different species.

Fig. 14. An imperfect valve, apparently with its dorsal edge downwards, but its abdominal segments in right position.

Fig. 15. An oblong valve or carapace, with an obscure adjunct; followed by an imperfect set of six segments (fig. 16); and associated with another but modified valve, fig. 17: fig. 7 also occurs in the same group as placed on the plate.

Report of the Committee, consisting of Professor JAMES GEIKIE (*Chairman*), Mr. S. A. ADAMSON, Professor T. G. BONNEY, Professor W. BOYD DAWKINS, Mr. WM. GRAY, Mr. ARTHUR S. REID, *and* Mr. OSMUND W. JEFFS (*Secretary*), *to arrange for the collection, preservation, and systematic registration of Photographs of Geological Interest in the United Kingdom.* (*Drawn up by the Secretary.*)

YOUR Committee have much pleasure in presenting the annexed List of Geological Photographs obtained as the result of their first year's operations.

In the Report of the Corresponding Societies' Committee presented to the Newcastle meeting (1889), lengthened reference was made to a proposal by the Committee of Section C. for the systematic collection and registration of geological photographs, following upon a suggestion contained in a paper read before the section at Bath by Mr. Jeffs. The subject was discussed several times by the delegates, many of whom contributed examples of such geological photographs as had been taken before any scheme to secure uniformity of action was mooted. Important suggestions were also offered as to the arrangements to be made to carry out the objects stated, but the details were ultimately left in the hands of the present Committee, the appointment of which was sanctioned at the Newcastle meeting.

In commencing operations, your Committee issued a circular inviting the co-operation of geological societies, field-clubs, photographers, and all others interested in supplying them with the following information, viz.:—

(1) Lists and details of photographs taken illustrating localities and sections.
(2) Names of local societies, or persons, who may be willing to further the objects of the Committee in their own district.
(3) Particulars of new localities, sections, boulders, or other features which it may be desirable to have photographed.

It was added that:

'The Committee will also be glad to receive a copy of the print from each negative, which will be exhibited at the succeeding meetings of the Association and afterwards preserved for reference. It is thus hoped to form, eventually, a National Collection of photographic views, illustrating the geology of our country and deposited in a centre where the collection will be available for purposes of study and comparison.'

In order to secure uniformity of action and as a guide to those willing to assist, a Circular of Instructions was issued, embodying those points which were thought to be most desirable in effecting the objects of the Committee. The details given were drawn up after very careful consideration and consultation with practical photographers, and were so framed as to be applicable to most of the conditions to be met with in photographing the different classes of objects having geological interest worthy of permanent record.

The following is a copy of this circular, which is given here for convenience of reference.

[CIRCULAR NO.

[Reduced Copy of FORM A.]

FORM A. BRITISH ASSOCIATION COMMITTEE ON GEOLOGICAL PHOTOGRAPHS.			No. of Photo.*
County of	Photographed under the direction of Society.		
Name and position of Locality or Section.			
Special features shown.			
Details of Section.	Height Length	Compass Direction.	'In shade' or 'direct light.' Time : a.m. p.m.
Sketch, or other particulars, if necessary, may be given here :—			
Name of Photographer Address	Date photographed		Registered No.

* This Number should also be placed on the back of the Photograph.

Instructions for the Collection of Geological Photographs.

Photographs are desired illustrative of characteristic rock-sections, especially those of a typical character or temporary nature; railway cuttings; important boulders; localities affected by denudation or where physiographical changes are in operation; raised beaches; old sea-cliffs; coast scenery and coast erosion; characteristic river-valleys, escarpments, and other landscape features; glacial phenomena such as *roches moutonnées*, moraines, drums, and kames, and natural views of geological interest.

I.—The views should be taken under skilled geological direction, and in every case the most typical views should be secured in preference to general views. It may be convenient for Societies to form a small committee for the purpose of noting suitable sections desirable to be photographed, and arranging such work as may be possible in each district. To this end it is anticipated that the services of many amateur photographers may be usefully brought into requisition.

II.—Size of photograph recommended: $8\frac{1}{2}$ by $6\frac{1}{2}$ inches ('whole plate'). (In view of the difficulty of carrying a heavy camera and plates it is not desired to exclude smaller views when these are well defined and clear. The size, therefore, is optional.)

The views should be printed by a permanent process whenever practicable.

III.—It is necessary, in order to preserve its scientific value, that each photograph should be accompanied by the following details, which may be given on forms supplied as per copy, and attached loosely to the photograph (not *fastened* on the back):—

(*a*) Name and position of section or locality.
(*b*) Special feature shown, with illustrative diagrams, when necessary. (Details may be given, if more convenient, on a separate tracing attached to the photograph.)
(*c*) Height and length of section, and compass direction.

(*d*) Name of photographer, and society under whose direction the view is taken.
(*e*) Date when photographed.
(*f*) Indication of direction of light and shade; *i.e.*, state whether taken in 'direct light' or 'in shade.'

IV.—Each photograph sent in for registration should bear a *local* number, and the accompanying form should be numbered in accordance therewith.

V.—Lists of photographs, copies of photographic prints and information relative thereto should be sent under cover to the Secretary to the Committee, *at the earliest possible date*, as the work of registration will be heavy.

The offers of help received in response to this circular were very numerous. The number of photographs sent in up to September reached a total of 275, a result which, taking into consideration the difficulties incident to a first year's working, the Committee feel is an encouragement to persevere in their efforts, if permitted to do so, until an adequately complete series of photographs is obtained. It will be seen from the list appended that a large majority of the English counties, besides those of Scotland and Ireland, are as yet almost entirely unrepresented, and that in the case of counties from which photographs have been received, the views taken have been confined to limited areas. Prior to the institution of this Committee, there has been little effort made to arrange for the systematic photographing of local geological sections, although much has been accomplished in an irregular manner by individual workers. It has been difficult to obtain all the particulars desired of these earlier photographs, but it is believed that the more important of them, at any rate, are included in the list attached to this report. Acknowledgment is due to those Societies (among which may be mentioned the Belfast Naturalists' Field Club, Chester Society of Natural Science, Croydon Microscopical and Natural History Society, Essex Field Club, Leicester Literary and Philosophical Society, Liverpool Geological Society, and the Yorkshire Geological and Polytechnic Society) for the care they had taken to preserve photographic records of important and interesting sections.

While a fairly large number of photographs has been obtained in response to the circular issued by the Committee, but little has been accomplished in the way of establishing county photographic surveys for geological purposes. It was hoped that the suggestion in Circular No. 2 as to the formation of special local committees in different centres (the only satisfactory means of doing the work thoroughly) would have been more widely adopted. The only counties which have so far undertaken such systematic work are Kent and Yorkshire. In the latter county that valuable aid to scientific progress, the 'Yorkshire Naturalists' Union,' has already aided the work of the British Association by the establishment of local committees charged with special objects of research. As soon as possible a geological photographic section was formed, of which Mr. James W. Davis was appointed chairman and Mr. James E. Bedford secretary. This section has sent over a hundred copies of photographic prints, with descriptions, the work of its members in the county of York besides other localities further afield. This Committee are much indebted to the officers of the Yorkshire Geological Photographic Section for their valuable assistance.

There are not wanting indications also of the ripening of the scheme in other directions at an early date.

Mr. J. Hopkinson, of St. Albans, read a paper before the Hertfordshire Natural History Society on 'Scientific Investigations in Hertfordshire in connection with the British Association,' in which he pointed out several geological features in the county worthy of being photographed, and urged the formation of a local collection of geological views, to be commenced during the summer of 1890.

An important proposal was brought before the Photographic Society of Birmingham by Mr. W. Jerome Harrison, who advocated a photographic survey of the county of Warwick, to include pictorial, architectural, besides antiquarian and scientific, subjects; and alluded specially to the work of this Committee.

Interest in the work of the Committee has been manifested abroad as well as in this country. Letters have been received from several foreign professors of geology asking for information and details of the scheme, and offering, in some cases, an exchange of photographs. Professor E. Reyer, of Vienna, Dr. A. Leppla, of Berlin, and Dr. G. Dewalque, of Liège, have each specially interested themselves in the objects of this Committee. Professor J. F. Kemp, of Cornell University, Ithaca, New York State, U.S.A., has also taken steps to bring the subject before the Geological Society of America, with the view to the inauguration of a similar scheme in America.

The Committee regard it as highly important that as many photographs of sections, &c., should be taken as possible. Of these a careful selection of the most typical views should be made to be sent in for registration. During the first year *all* views sent in have been registered, but in future it will be necessary to make a selection of those most suitable, otherwise there will be an accumulation of photographs illustrating the same section or natural feature.

It has been found quite impracticable to restrict photographers to any special size of print; it is therefore merely recommended that the plate should be as large as possible, the 'whole plate' size ($8\frac{1}{2}$ by $6\frac{1}{2}$ inches) being the most suitable.

Your Committee have not yet had an opportunity of fully discussing the question of the ultimate disposition of the photographs, and it has been thought advisable to defer a recommendation of this nature until a more complete series of photographs has been obtained.

Meantime a suggestion has been made by Mr. Willem S. Logeman, principal of Newton School, Rock Ferry, that a volume of selected photographs, illustrating typical geological features, should be published, which would form a useful book of reference for educational purposes. At present the collection of photographs is not of sufficient proportions to warrant the reproduction of a really complete series of views from nature, such as it would be of advantage to students and others to possess; but the Committee are bearing in mind the suggestion for possible use in the future, should they see their way to recommend its adoption.

It is with great regret that the Committee have to record the decease of Mr. S. A. Adamson, who was a most active member, and to whose exertions and influence the progress of the work in Yorkshire is largely due.

The Committee desire to express their obligations to Mr. A. Norman Tate, editor of *Research*, for the loan of a block for the purpose of illustrating their Circular of Instructions.

The work of the Committee having been, so far, of a preliminary nature, they would respectfully solicit their reappointment, in order to arrange for the further completion of the objects for which they were appointed, with a renewal of the grant of ten pounds.

FIRST LIST OF GEOLOGICAL PHOTOGRAPHS.
(TO SEPTEMBER 1890.)

NOTE.—This list contains the subjects of all geological photographs known to have been issued. Copies of those *only* to which the *registered No.* is attached have been received by the Secretary of the Committee.

Copies of any photographs desired can, in most cases, be obtained either from the photographer direct (whose address is usually given) or from the officers of the local society under whose auspices the views were taken.

The Committee in no case has assumed the copyright of photographs registered, which is presumed to be held by the photographer.

The price at which the photographs may be obtained depends upon the size of print and local circumstances, over which the Committee has no control.

CHESHIRE.

Liverpool Geological Society—per W. HEWITT, *Secretary.* (*Photographed by* E. NEWALL, 14 *Elm Grove, Tranmere.*) *Size* $8\frac{1}{4} \times 6\frac{1}{2}$ *inches.*

Regd. No.		
1, 3, 4, 5	Storeton Quarry, 1887 .	Various sections
2	" " 1887 .	'Footprint bed'
6	Wallasey, 1887 . . .	Quarry in Lower Keuper
7, 8	" Breck Road .	Section showing 'current bedding'
9	Prenton Lane, Birkenhead, 1887	Junction of Keuper and Bunter
10	Bidston Hill, 1887 . . .	Fissile Keuper sandstone
11	Hilbre Island (mouth of River Dee)	Bunter
12, 13	" " (Middle Island)	Conglomerate bed
14	Thurstaston Hill, 1887 .	'Thor's Stone,' an outlier of the Bunter
15	West Kirby, 1887 . .	Fault at Calday Grange
16	" " " . .	Junction of Keuper and Bunter
	Flaybrick Hill, 1887 . .	Ditto
	" " 1885 . .	Fault in Keuper
	" "	Roche moutonnée
	Poulton Quarry, Wirral, 1885 (2)	Jointing in Keuper

Per J. LOMAS, 23 *Avondale Road, Liverpool.*

Dawpool, Wirral, 1888 (4) .	Boulder clay cliffs on bank of River Dee showing interbedded sands, &c.
Hilbre Island (2) . .	Coast erosion
Wallasey (2) . . .	Sand dunes, showing stratification
" Breck Road . .	'Contortions' in Trias
Ince	Peat beds
" (Ship Canal Sections)	Fault in Trias

Photographed by E. TIMMINS, *Runcorn.*

32	Runcorn (lane to Higher Runcorn)	Frodsham beds of Keuper

Cornwall.

Photographed by Percy F. Kendall, 31 *Parkfield Street, Manchester.*

Lands End . . .	Columnar jointing
St. Erth	Pliocene clays
,, ,, ...	Contorted strata
,, ,, ...	Pliocene sand resting on elvan

Per Rev. H. H. Winwood, 11 *Cavendish Crescent, Bath.*

36	Mitford Tunnel . . .	Mitford sands
37	Tucking Mill . . .	William Smith's House
38	,, ,, . . .	Tablet to the memory of William Smith ('Father of English Geology')

Devonshire.

Photographed by J. J. Cole, *Maryland, Sutton, Surrey.*

57	Lulworth (Stare Cove) .	Showing contorted strata

Per W. Pengelly, *Lamorna, Torquay.* (*Photographed by* William Widger, 44 *Union Street, Torquay.*)

58	Torquay	Entrance to Kent's Cavern
59	,, ...	,, ,, Brixham Cave

Isle of Man.

Photographed by Ed. Newall (*Liverpool Geological Society*).

31	Scarlett Point	
30	Port St. Mary . . .	Glaciated limestone surface

(And some others not designated.)

Per Yorkshire Naturalists' Union (*Geol. Photo. Section*). (*Photographed by* S. A. Warburton, 9 *Banstead Terrace, Leeds.*) *Size* 8 × 5 *inches.*

75	Douglas Head, 1885 . .	Contorted slate

Photographed by J. E. Bedford, 9 *Cardigan Road, Leeds. Size* 8 × 5 *inches.*

76	Scarlett Stack, 1888 . .	Basaltic boss
77	,, ,, ,, . .	,, ,, (with dyke)
78	Scarlett Point ,, . .	Upheaved limestone
79	,, ,, ,, . .	Weathered volcanic ash

Kent.

Per Arthur S. Reid, *Trinity College, Glenalmond, N.B.* (*Photographed by* Professor E. W. Reid, *University College, Dundee.*)

224	Elham Valley Railway, 1889 (1)	Large pipe in Chalk
225-226	,, ,, ,, (2)	Junction of Thanet Beds and Chalk
227	,, ,, ,, (1)	Thanet Beds

Per East Kent Natural History Society, Geological Photo Sub-Committee. (Photographed by C. W. ALLEN, *19 St. Dunstan's Street, Canterbury.)*

228–229	Elham Valley Railway, 1889 (4)	Junction of Thanet Beds and Chalk
230	„ „ „ (1)	Large pipe in Chalk
231	„ „ „ (1)	Large pipe in Chalk
232	„ „ „ (1)	Drift on Chalk
233	„ „ „ (1)	Thanet Beds

LANCASHIRE.

Photographed by E. NEWALL *(Liverpool Geological Society).*

17, 18	Woolton, Liverpool . .	Two views of the 'Calderstones' (stone circle)

Photographed by E. WARD, *249 Oxford Street, Manchester.*

Series of views of the 'Oxford Road Boulder,' now in the Quadrangle of Owens College, Manchester

„ „ „ Manchester Ship Canal

Photographed by GODFREY BINGLEY *(Leeds Geological Association), for the Yorkshire Naturalists' Union (Geol. Photo. Section). Size* 4 × 2¾ *inches.*

91, 92	Lindale, near Grange, 1889 (2)	Old sea cliffs in Carboniferous limestone
93–97	Hampsfell „ (5) .	Escarpment in limestone showing weathering
98–105	„ „ (8) .	Weathered Carboniferous limestone
106–108	„ „ (3) .	Limestone boulders lying on Carboniferous limestone
109–117	„ „ (9) .	Erratic boulders (various) lying on Carboniferous limestone

LEICESTERSHIRE.

Leicester Literary and Philosophical Society—per JAMES PLANT, *West Terrace, Leicester. (Photographed by* JOHN BURTON & SONS, *Leicester.) Size* 12 × 10 *inches.*

29	Croft Hill, July 1881 .	Syenite, Trias, and Boulder clay
	„ „ May 1882 .	„ „ „ „ „
	Barrow-on-Soar, June 1881	Arches in Lias limestone
	Mount Sorrel, July 1875 .	Hornblendic granite
	„ „ Sept. 1877 .	„ „
	Humberstone, May 1881 .	The 'Holystone' erratic
	Broombriggs, Charnwood Forest, July 1875	Charnwood slate
	Benscliff, Charnwood Forest, July, 1875	„ „
	'Hanging Stone,' Charnwood Forest, August 1881	„ „
	Woodhouse Eaves, Charnwood Forest, June 1881	„ „
	Saffron Lane, Leicester, June 1882	Boulder clay, &c.
	Breakback Hill, Charnwood Forest, June 1881	Keuper, lying upon Charnwood slate
	Ring Pit Quarry, Charnwood Forest, June 1881	Concentric rings in slate

	Swithland, Charnwood Forest, June 1881	Slate
	Stoney Stanton, June 1881	Southerly extension of Charnwood rocks
28	Aylestone, 1881 . . .	Erratic block of Mount Sorrel granite

MONTGOMERYSHIRE.

Caradoc Field Club. (Photographed by W. W. WATTS, *Sidney College, Cambridge.)*

88–89	Corndon Hill (S.E.), 1885 (12A)	Dolerite, resting on shales, Base of Corndon laccolite
90	„ „ (W. side) .	Middle Arenig shales resting conformably on dolerite

NORTHUMBERLAND.

Per W. W. WATTS. *(Photographed by* G. HINGLEY, *Cullercoats, Newcastle-on-Tyne.)*

197	Caves on Coast . . .	Jointing and bedding in Coal measures
198	Near St. Mary's Island .	Curved faults in Coal measures
199	Tynemouth . . .	Magnesian limestone
200–201	Marsden Bay . . .	Breccia gashes in Magnesian limestone
202	'The Stack' . . .	„ „
203	'Lot's Wife' . . .	Sea stack
204	Marsden Rock . . .	„
205	Marsden Bay . . .	Concretions in Magnesian limestone

NOTTINGHAM.

Photographed by JOHN BURTON & SONS, *Leicester.*

Nottingham, June 1882 .	Church Cemetery; caverns in Pebble Beds
„ „ „ (2)	Castle Hill, Bunter
Himlack (or Hemlock Stone)	Showing denudation

Per JAMES SHIPMAN, *Manning Grove, Nottingham.*

Nottingham Castle . .	Pebble beds
Kimberley	Permian, resting on tilted Coal measures
Hemlock Stone, Nottingham	
Nottingham . . .	Faulted Keuper
Blidworth . . .	Outliers of Keuper (supposed 'Druidical' remains)
Beeston	Interglacial sand and river gravel

NORTH WALES.

Chester Society of Natural Science—per GEORGE FRATER, *The Bank, Wrexham. (Photographed by* ALFRED O. WALKER, *Nant-y-Glyn, Colwyn Bay.) Size* 6 × 4 *inches.*

42	Cefn Beuno Caves, Vale of Clwyd	
43, 45, 46, 47	Cefn-y-bedd, Wrexham	
44	Holywell, Bagillt . .	Lower Coal measures
48	Colwyn Bay, Pen-y-Bont Farm, 1889	Drift with alternate beds of clay and sand

Leeds Geological Association—per J. E. BEDFORD. (*Photographed by* GODFREY BINGLEY, 15 *Cardigan Road, Leeds, for the Yorkshire Naturalists' Union, Geol. Photo. Section.*) *Size various.*

118	Llandudno, Great Orme's Head	Erratic boulder
119–121	„ „ „ .	Weathered blocks of Carboniferous limestone
122	„ „ „ .	Escarpment of Carboniferous limestone
123	„ „ „ .	Section in limestone quarry
124–128	„ „ „ .	Cliffs showing stratification
129–131	„ „ „ .	Fissure in limestone
132–137	„ „ „ .	Views of cliff sections

SHROPSHIRE.

Caradoc Field Club. (*Photographed by* W. W. WATTS, *Sidney College, Cambridge.*) *Size* $4 \times 3\frac{1}{2}$ *inches.*

80	Minsterley (road to Bishop's Castle), 1887 (1)	Section at Hope Dingle showing unconformable junction of Silurian on Ordovician
81	„ (near Fox Inn) (3)	Basin produced by folding of beds of Middle Arenig ash
82	Pontesbury (Nills Hill), 1887 (6)	Stiperstones Quartzite
83	„ „ (7) .	„ „
84	Minsterley (Tasgar Quarry) (8)	Upper Arenig ash
85	Whittery Bridge (9) . .	'Whittery' ash (Bala, or Lower Caradoc age)
86	Wotherton (Barytes Mine), 1885 (10)	Fault in 'Whittery' ash
87	Todleth Hill (E. Side), 1885 (11)	Crags overlooking Hurdley, columnar intrusive andesite
	Much Wenlock . . .	Wenlock limestone
	Wrekin, from Benthall Edge	
	Broseley (Corbett's Dingle)	Bedding and jointing in Carboniferous sandstone

SOMERSET.

Per Professor C. LLOYD-MORGAN. (*Photographed by* H. B. JUPP, *Clifton College, Bristol.*)

SERIES OF GEOLOGICAL SECTIONS ON THE AVON GORGE.

207	Clifton	Dolomitic conglomerate
208	„	Massive Oolitic limestone
209	„	Massive Dolomitic conglomerate resting on Old Red sandstone
210	„	Fault. Millstone grit and Upper Limestone shales
211, 213	„	Bryozoa bed in Lower Limestone shales

YORKSHIRE.

Per ARTHUR S. REID, *Trinity College, Glenalmond, N.B.* (*Photographed by* Professor E. W. REID, *University College, Dundee.*)

39, 40	Draughton, near Skipton .	Contorted Carboniferous limestone
41	Bolton Abbey Station .	Faulted synclinal in limestone

Yorkshire Geological and Polytechnic Society—per James W. Davis, *Chevinedge, Halifax. Size* 11 × 8 *inches.*

19	Raygill Quarries, with fissures, 1875	
20	Plumpton Rocks, 1879 .	
21	Scarboro' Castle, 1883 .	Nodular concretions in calcareous grit.
22	Wadsley, near Sheffield, 1876	Fossil trees in Lower Coal measures
23, 24	Flamboro' Head, 1882 .	Erosion of chalk
25	,, Thorwick Bay .	Chalk surmounted by drift
26	Clayton, near Halifax, 1886	Roots of stigmaria
27	Hilderthorpe, 1887 . .	Current-bedded sands
	Draughton, 1871 . .	Contorted limestone
	Moughton Fell, 1877 . .	Junction of Silurian with Carboniferous limestone
	Gordale Scar, 1878 . .	
	Raygill Fissure, 1880 .	(During exploration)
	Norber, 1881 . . .	Erratic blocks
	Bempton Cliffs, 1885 . .	Contorted chalk

Per Yorkshire Naturalists' Union (Geol. Photo Section). (Photographs taken for the Leeds Geological Association, by F. W. Branson, 14 *Commercial Street, Leeds.) Size* 7 × 5 *inches; enlarged series,* 14 × 10 *inches.*

138	Longley's Brick Works, Leeds	Coal measures above 'Beeston' bed
139	Grosvenor's Yard . .	'Beeston' bed (8 to 9 feet) and Coal measures
140	Boyle's Quarry . . .	General Section, 'Crow coal' and Coal measures above and below
141	,, ,, . . .	,, ,, (detailed)
142	Dolly Lane, Brick Yard .	'Black red' coal
143	Benson Street, Brick Yard .	'Better bed' coal, &c.

[Note.—These were photographed in 1885, and were temporary sections, but extremely valuable as showing the succession in the Lower Coal measures from above the 'Beeston' bed to those immediately above the Elland flagstone.—S. A. Adamson.]

Photographed by J. E. Bedford, *Cardigan Road, Leeds (for Leeds Geological Association). Size* 6 × 4 *inches.*

144	Armley, near Leeds, 1882 .	Elland flagstones; ruptured shales and flagstones
145	Draughton, near Skipton, 1885	Contorted limestone (anticlinal and synclinal)
146	,, ,, 1885 .	Slickenside at side of an anticlinal
147	Bridlington, 1886 . .	Cross-bedding in gravel
148	,, ,, . . .	Freshwater gravel on boulder clay
149	,, ,, . . .	Lake deposit lying on boulder clay
150	Filey, 1886 . . .	Drift lying upon Oolitic limestone, showing atmospheric denudation
151	,, ,, ...	(as above)
152	The Brigg, Filey . .	Oolitic beds at the Brigg

Photographed by A. E. Nicholls, *Borough Engineer's Office, Leeds (for Leeds Geological Association). Size* 6 × 4 *inches.*

153–5	Castleford, 1890 . .	Three views of fossil tree stem *in situ* in Coal measures
156	Haddockstones, 1889, between Markington and Ripon	Isolated blocks of Plumpton grit

157, 158	Sections on new railway, 1889, Ilkley to Skipton .	Vertical and contorted Carboniferous limestone
159–164	Garforth and S. Milford, 1889	Six views of quarries in Magnesian limestone, showing methods of quarrying and varieties in bedding
165	Knaresborough Castle, 1888	Base of Magnesian limestone, with underlying '3rd' grit
166	" " 1888	Plumpton rocks
167	Dudley Hill, Bradford, 1890	Lower Carboniferous sandstone
168, 169	Brough, near Hull, 1889 .	Post-tertiary gravels, resting on Oolitic outlier at base of the chalk wolds

Photographed by Godfrey Bingley (*for Leeds Geological Association*), 15 *Cardigan Road, Headingley, Leeds. Size various.*

170, 171	Burnsal, near Skipton, 1890	Ridge of limestone crossing valley of the Wharfe
172	Saltburn, 1888 . . .	View of drift hills
173	" " . . .	Valley cut in drift
174	" " . . .	Sandhills and drift
175	" " Hunt Cliff, 1888	Middle Lias and ironstone band
176	Whitby Scar, 1888 . .	Lias and Oolite
177	Staithes (Penny Nab), 1888	Middle Lias
178	" (Colborn Nab), 1888	"
179	Hayburn Wyke, near Scarborough, 1887	Sea cliff and waterfall
187	" " " .	Lower shale and sandstone, Oolite
180	Thornton Force, Ingleton, 1890	Base of Carboniferous limestone, resting unconformably on Silurian
181–184	Norber, near Clapham, 1889	Erratic blocks of Silurian grit resting on Carboniferous limestone
185	Ewe Nab, Carnelian Bay, 1887	
186	Scarborough Cliffs, near the Spa	
188	Headingley, Leeds, 1888 .	Cliff in Lower Coal measures
189, 190	Adel Moor, Leeds, 1890 .	Large weathered blocks of Millstone grit (*in situ*)
191	Bolton Abbey . . .	Yoredale shales
192	Bolton Woods, 1888 . .	Valley of the Strid through Millstone grit
193	Flamborough, 1887 . .	Arch in chalk cliff
194	" " . .	Chalk cliff
195	" Thornwick Bay	Caves in chalk
196	" " " .	Showing marine erosion of chalk beneath and atmospheric action denuding drift above

Photographed by the Rev. W. H. Fox, *Thixendale, York.*

214	Cutting at Enthorpe, on Driffield and Market Weighton Railway	Horizontal layers of flint in Middle Chalk
215	Craike Hill . . .	False bedded sands and gravel
216	Weedly	Band of Black Chalk

Photographed by Miss McCallum, *Clarence House, Filey.*

219–221	Filey Brigg . . .	Marine erosion

Photographed by G. FOWLER JONES, *Quarrybank, Malton.*

222	Settrington Bridge . .	Fault in Coralline oolite
223	Gravel Pit, Malton . .	Highly inclined beds of Oolitic gravel

SCOTLAND.

Per ALEX. ROSS, *Marldon Chambers, Inverness.* (*Photographed by* D. WHYTE, *Inverness.*) *Size* $8\frac{1}{2} \times 6\frac{1}{2}$ *inches.*

54–56	Island of St. Kilda (looking N.W.), 1885	Three views showing weathering and form of gabbros and volcanic rocks

Photographed by R. McF. MUIR, 35 *Underwood, Paisley.*

33–35	Partick, near Glasgow .	Three views of fossil trees in Coal measures at Whiteinch
49	Gleniffer Braes, Renfrewshire, 1885	Nethercraig's lime quarry, showing master-joints

Per ED. WARD, 249 *Oxford Street, Manchester.* (*Photographed by* PERCY F. KENDALL.)

ISLAND OF MULL.—Series of 17 quarter-plate views.

Salen Shore	Dykes
„	Intrusive basalt
„	Columnar dyke
Arches, Mull . . .	„ with tachylite
„	Cave above tide mark
„	Spheroidal weathering of basalt
Port, Bean	Faulted dyke
Gribun	Cliffs and talus
Carsaig	Marine denudation
Staffa	Columnar basalt
„	Curved basaltic columns

Photographed by W. NORRIE, 28 *Cross Street, Fraserburgh, under the direction of* Professor HEDDLE *and* L. A. HARVIE-BROWN. *Size* 5×8 *inches.*

[Local numbers in brackets.]

60	Island of Rum, 1889 [3] .	Stack of Mharagast
61	Bird's Island, Caithness, 1887 [7]	View of Holborn Head
62	Holborn Head (E. side) [8]	Flagstone
63	Ross of Mull [9] . .	Basaltic colonnade (the last of the twin columns)
64	„ Nun's Cave [11] .	Basaltic arch
65	Holborn Head . . .	Rift in rocks
66	„ 'Devil's Bridge' [12]	Caithness flagstone
67	Ross of Mull (looking through Nun's Cave)	
68	Gribun, Mull [19] . .	Clustered basalt
69	„ „ [20] . .	Basaltic pavement
70	„ „ [21] . .	Trap dyke in basalt
71	„ „ [22] . .	Rent in trap dyke
72	Shiant Island [37] . .	Basaltic north cliff
73	Whitenhead Stack [54] .	Contorted gneiss
74	„ „ [65] .	North end of great fault through Scotland

Photographed by G. W. WILSON & CO., *Aberdeen. Selected list by* Professor JAMES GEIKIE.

[NOTE.—The numbers in brackets are those of the photographers, and are inserted for convenience of reference]

Large size, $11\frac{1}{4} \times 7\frac{1}{2}$ *inches.*

West side of Handa, Sutherland [2025]	Sea coast section of horizontal Torridon sandstone
Assynt Lodge, Sutherland [2031]	Archæan gneiss in foreground, overlooked by escarpments of Torridon sandstones (so-called Cambrian)
Lochnagar [2551] . .	Corrie with tarn, in granite
The Door Holm, Tangwick, Shetland [2070]	Sea-stack or islet: Old Red sandstone lava-form rocks and agglomerates, showing denudation since period of glaciation
Granite quarries, Aberdeen [4048]	Granite
Buchan Coast, near Stains [4036]	Granite: showing structural features and their influence in marine erosion
Granite quarries, near Bullers-of-Buchan [4038]	Granite: structural features
Cior Mhor from top of Goat Fell [5742]	General view of granite mountains, sharp crests, corries, torrent-courses, and screes
'Cyclopean Walls,' Arran [5739]	Granite mountains; knife-edged ridges of granite; weathering and débris; trap dykes cutting granite
Ben Nuish from top of Goat Fell [5743]	Corries, torrent-courses, &c., in granite
Carse of Gowrie from Kinnoul Hill [6601]	Old fluviatile and estuarine flat
Loch Maddy, North Uist [6174]	Characteristic landscape (Archæan rocks)
Spindle Rock, St. Andrews [6269]	Radiating columnar basalt, tuff, &c.
The Old Man of Hoy [128]	Weathering of Upper Old Red sandstone; sea coast; influence of joints
The Pot, Bullers-of-Buchan [204]	Sea action on granite; influence of joints
Dunbay Rock, Buchan Coast [205]	Sea action
Dunotter Castle [494] .	Sea cliff—vertical Lower Old Red conglomerate
Gordie Stack and Drongs, Shetland [582]	
The Old Man, Storr, Skye [873]	Weathering of bedded basalt rocks
The Quiraing, Skye [893–97]	Weathering of bedded basalt
The Kilt Rock, Skye [898]	Columnar basalt resting on Mesozoic strata
The Old Man of Wick [936]	Caithness flags (Old Red); sea coast action; influence of joints in formation of caves and stacks
The Stack of Brough, Wick [939]	" " " " "
Clamshell Cave, Staffa [762]	Curved columnar basalt
West side of Staffa [765] .	Columnar and amorphous basalt
Boat Cave, Staffa [766] .	" " " " and tuff
Colonnade, Staffa [767] .	" " " " "
Causeway of bending pillars, Staffa [768] .	Amorphous basalt above curved columnar basalt
Island of Staffa [2454] .	General view

Colonnade and Boat Cave from the sea [2477A]	General view
Fingal's Cave . . .	Three views, showing amorphous and columnar basalt
Parallel Roads in Glenroy [1234]	
North Galton, Orkney [1450]	Old Red flagstone; influence of joints
Muchalls, sea cave [1734?]	Granite
Suilven, Assynt, Sutherland [1968]	Torridon sandstone outlier; Archæan rocks
The Maddys, Loch Maddy [6090]	Characteristic landscape of Archæan gneiss; roches moutonnées (weathered)
Looking up Loch Eport [6174]	Archæan gneiss
The Grind of the Naver, North Maven [2051]	Structural features of bedded, lava-form rocks (Old Red) and their influence on marine erosion
Scuir-na-Gillean, Skye [859]	General view of gabbro mountains; moraine in foreground

Smaller size, 8 × 5 inches.

The Brig o' Trams, Wick [1567]	Action of sea on Old Red sandstone
The Drongs, Shetland [580]	Sea stacks
The Quiraing, Skye [384] .	Weathering
The Lion Rock, Cumbrae [1290]	Basalt dyke
Samson's Ribs, Edinburgh [872]	Columnar basalt
East side of Staffa [1464]	Curved basalt
Spindle Rock, St. Andrews [929]	Radiating columnar basalt in tuff
Fiddle Bow Rock, Cullen [6058]	Marine erosion in crystalline schists
The Gloop, Duncansby Head [1586]	Old Red sandstone
Ben Stack, Sutherland [2739]	Archæan gneiss
Stacks of Duncansby [1585]	Marine erosion
Noss Head, near Wick [1576]	Caithness flags
Cliffs on Handa, Sutherland [2735]	Torridon sandstones
Windy Edge Pass, Dollar [2154]	Stream following joint in igneous rock of Old Red sandstone age
Inchnadamph, outflow of underground river [2684]	Bared thrust-plane in limestone
Kurka Stack, Balta, Shetland [2680]	Islet of gabbro
Holm of Noss [568] . .	Marine action along joints in Old Red sandstone
Stack Sheog, Handa [2738]	Marine erosion in Torridon sandstones
The Pot, Bullers-of-Buchan [973]	Marine action in granite. The 'Pot' is a 'tunnel,' the roof of which has fallen in
The Giant's Leg, Bressay [665]	
The Needle-Ee Rock, Wick [2613]	Marine erosion in Old Red sandstone
Linn of Dee, Braemar [3657]	River action; cutting in crystalline schists
Staffa: Colonnade and Fingal's Cave [4575]	Columnar basalt

Valley of the Thousand Hills, Glen Torridon [591]	General view of moraines
Inchnadamph and Ben More [2685]	Limestone beds piled up by thrusting from east
Doune of Invernoghty, Strathdon [6890]	Alluvium and relics of old river terrace
The Herdsman Island, Staffa [1460]	Bird's-eye view of columnar basalt
Linn of Gnoich, Braemar [10143]	River cutting through schists along lines of joints
'Gulgh' at the Linn . .	Pot holes in bed of river

Ireland.

Belfast Natural History and Philosophical Society—per W. Swanston, *King Street, Belfast.*

52	Whitehead, Belfast, 1889 .	Columnar basalt resting on eroded surface of chalk
53	Whitewell, Belfast, 1889 .	Amygdaloidal basalt resting on indurated chalk

Belfast Naturalists' Field Club—per Wm. Gray, 8 *Mount Charles, Belfast.* (*Photographed by* R. Welch, 49 *Lonsdale Street, Belfast. Size full plate.*)

234	The Grand Causeway, Co. Antrim	Columnar basalt
235	The Wishing Chair, Co. Antrim	,, ,,
236	The Fan, Co. Antrim . .	,, ,,
237	The Honeycomb, Co. Antrim	,, ,,
238	Amphitheatre, Co. Antrim	Columnar basalt and interstratified beds of bole, &c.
239	The Giant's Gateway .	Columnar basalt
240	Middle Causeway . .	Horizontal and vertical columns
241	Pleaskin Head . . .	Columnar, tabular and decomposed beds of basalt
242	Dunseverick	Detached boss of basalt
243	Needle Rock, Portcarn .	Marine denudation
244	Greyman's Path . . .	Atmospheric denudation
245-246	Fan Head, from the sea .	Columnar basalt
247	Rocking Stone, Island Magee	Transported block of trap rock
248	Cloughmore, Co. Down .	Transported block of granite
249	Great Cave, North Coast, Co. Antrim	Marine denudation of chalk
250	Garron Point, North Coast, Co. Antrim	Landslip
251	Slieve Bingian, Co. Down .	Atmospheric denudation of granite
252	The Quarry, Carlingford, Co. Louth	Carboniferous limestone, with intrusive basalt
253	Knockmore, Co. Fermanagh	Mouth of ossiferous cave

Photographed by W. Stilfox, *Belfast.*

254	North Coast, Co. Antrim .	Denudation of chalk
255	Kenbane, ,, .	Headland of chalk
256	Cave on North Coast, Co. Antrim	Chalk
257-258	Garron Point, Co. Antrim .	Chalk and basalt
259	North Coast, ,, .	Cliffs of chalk and basalt

260	Ballantry, Co. Antrim	Marine denudation
261	Elephant Rock, ,,	,, ,,
262-263	Chalk Cliffs, ,,	,, ,,

Photographed by WM. GRAY, 8 *Mount Charles, Belfast.*

264-265	Larne Gravels	Raised beach with worked flints
266	Fan Head	Transported block of trap
267	Strongford Lough, Co. Down	,, ,,
268	Fan Head	Columnar trap
269	North Coast, Co. Antrim	Denudation of chalk
271	Ballywillin, ,,	Curved columns of basalt
272	Doniaghey, ,,	Outcrop of New Red sandstone
273	Cushendun, ,,	Cave in Old Red conglomerate

Photographed by E. TATE, *Belfast.*

275	Whitehead, Co. Antrim	Boulder clay, columnar trap and chalk

Photographed by G. W. WILSON & CO., *Aberdeen (a selected series of photographs revised by* Professor JAMES GEIKIE).

[NOTE.—The numbers in brackets are those of Messrs. Wilson & Co., and are given for convenience of reference.]

Giant's Causeway [219]	Columnar basalt
,, ,, [225]	Ladies' wishing chair; nearer view of columns
,, ,, [226]	The Keystone, showing tops of columns
,, ,, [227]	The Fan (similar to No. 226)
,, ,, [229]	The Organ (radiating columnar basalt)
,, ,, [230]	Pleaskin Head (columnar and amorphous basalt)

Report of the Committee, consisting of Professor FLOWER (*Chairman*), Professor M. FOSTER, Professor RAY LANKESTER, Professor VINES, *and* Mr. S. F. HARMER (*Secretary*), *appointed for the purpose of arranging for the occupation of a Table at the Laboratory of the Marine Biological Association at Plymouth.*

THE grant of 30*l.* which was made to this Committee was recommended by the Committee of Section D on the assumption that this sum would be large enough to enable the use of a table at the Plymouth Laboratory to be acquired for a complete year. The Committee, on their appointment, at once entered into negotiations with the Council of the Marine Biological Association, in order to arrange the terms of payment to be made for the use of a table. By the payment of 500*l.*, made by successive instalments in accordance with recommendations adopted at the meetings in 1884, 1886, 1887, and 1888, the British Association had become a 'Governor' of the Marine Biological Association; and it had thereby acquired the permanent right of appointing one person in each year to occupy a table at the Laboratory at Plymouth for *one month* free of charge.

Under these circumstances, the Council of the Marine Biological Association agreed to allow the Committee to obtain a table at Plymouth for one year on payment of 30*l.*, instead of the normal subscription of 40*l.*

The Committee felt, however, that it would be advisable to defer making any final arrangement with the Council of the Marine Biological Association until applications to occupy the table had actually been received. It was recognised that applications for nomination to the use of the table would probably be received principally during the summer months, when persons who could be expected to make a good use of the nomination would be most likely to be able to spare time to work at Plymouth, and the results have justified this anticipation.

Three applications were actually received, and in each case the applicant desired to work at Plymouth during July and August. The Committee decided in consequence to give up the original intention of taking one table for the whole year, and to make use of the grant entrusted to them in hiring tables for those months in the year for which applications from suitable persons were actually sent in, thereby allowing them to nominate two or more persons to work simultaneously at Plymouth. This arrangement was finally made, with the consent of the Council of the Marine Biological Association, it being understood that the British Association had the right to the use of a table for one month in the year free of charge. By this arrangement, the grant of 30*l.* was sufficient to enable the Committee to acquire the use of a table for seven months, for one of which no payment was to be made, while the remaining period was to be paid for at the rate of 5*l.* per month.

The nominations which have actually been made are as follows :—

Mr. M. F. Woodward, Demonstrator in Zoology at the Science and Art Department, South Kensington, for two months (end of July to end of September).

Mr. W. G. Ridewood, B.Sc., for two months (July–August).

Mr. E. A. Minchin, B.A., of Keble College, Oxford, for three months (July–September).

The researches undertaken by these gentlemen are at present in progress, and it is obviously as yet impossible to give any final report on the results arrived at. The following preliminary statements have, however, been received. It must be pointed out that the report was written, in each case, shortly after the commencement of the occupation of the table.

I. *Report on the Occupation of the Table. By* Mr. M. F. Woodward.

The line of research to which I intend devoting my attention is that of Molluscan anatomy, especially that of the *Lamellibranchiata.* Several attempts have been made lately to re-classify the Lamellibranchs, as it is very doubtful if the older classification by muscular impressions can be adhered to in the light of recent investigations. The most recent classifications are by means of the gills; one by Fischer based on the number of gill lamellæ, and another by Pelseneer taking the *form* of the gill as a basis. Unfortunately, these two classifications differ from one another in important respects.

I hope, by making use of the facilities offered by my nomination, to work out the *general anatomy* of a number of forms; and, by carefully comparing these with one another, to ascertain if possible which, if either, of these classifications appears the most natural. I have, moreover, no doubt that many points of interest, both in the anatomy and in the histology of the *Lamellibranchiata*, will also be observed.

II. *Report on the Occupation of the Table. By* Mr. W. G. RIDEWOOD.

On the Air-bladder of Clupeoid Fishes.

The air-bladder of the herring communicates by a *ductus pneumaticus* with a backward prolongation of the stomach; it also communicates directly with the exterior, in the region of the anus, by a small papilla, which opens just within the aperture of the short urinogenital chamber or sinus.

The anterior end of the air-bladder is continued, after two bifurcations, into four sacs, each of which lies within its own tightly-fitting bony capsule. The anterior pair of sacs are in intimate contact with a pair of cæcal processes of the membranous vestibule of the ear, while the posterior pair are situated within the loop of the horizontal semicircular canal.

Although Weber[1] gave an excellent account of this anterior termination of the air-bladder in 1820, it would appear that of the whole of the clupeoid fishes only the common herring (*C. harengus*) has been minutely studied with reference to this arrangement, and the object of the projected investigation is to determine how far these complicated relations obtain in the closely allied species and genera.

In view of the great complexity of these relations it would be reasonable to expect a certain amount of variation in the allied forms, while, if the investigation be attended with the opposite result, it will tend to show that the system of classification of these fishes now adopted by ichthyologists is a true and a natural one.

III. *Report on the Occupation of the Table. By* Mr. E. A. MINCHIN.

I am investigating the structure and life-histories of the various species of Gregarinids parasitic on marine animals, especially those inhabiting *Holothuria*. I have already obtained and studied three species which I believe to be as yet undescribed, and which are parasitic on *Nebalia*, *Gammarus locusta*, and *Phallusia mammillata* respectively. I have also found several stages of the Gregarine inhabiting the body-cavity of *Holothuria*, described very inadequately by Schneider in 1858 in the 'Archiv f. Anat. u. Physiol.,' and have obtained some good results by studying this form by means of sections. I have also, incidentally, made a number of observations on the corpuscles in the body-cavities of *Holothuria* and *Echinus*.

I hope to be able to work out the minute structure of the Gregarine nucleus and its behaviour during conjugation and encystment, using sections and other methods for the purposes of this investigation.

The experience gained by the Committee during the past year has convinced them that the grant made by the Association has been of material service in assisting well-qualified persons who were anxious to work at the Laboratory at Plymouth. The investigations which are now

[1] *De Aure et Auditu Hominis et Animalium.*

in progress are of course unfinished, but the Committee are of opinion that the results are sufficiently encouraging to justify them in asking the Association to renew the grant for another year.

Third Report of the Committee, consisting of Professor FLOWER (*Chairman*), Mr. D. MORRIS (*Secretary*), Mr. CARRUTHERS, Dr. SCLATER, Mr. THISELTON-DYER, Dr. SHARP, Mr. F. DU CANE GODMAN, Professor NEWTON, Dr. GÜNTHER, *and* Colonel FEILDEN, *appointed for the purpose of reporting on the present state of our knowledge of the Zoology and Botany of the West India Islands, and taking steps to investigate ascertained deficiencies in the Fauna and Flora.*

THIS Committee was appointed in 1887, and reappointed in 1888 and 1889.

During the past year chief attention has been directed to the exploration of the island of St. Vincent, and two collectors have been maintained in that island at the expense of Mr. F. Du Cane Godman, who has kindly assisted the Committee in this manner in order that the funds at its disposal may be chiefly applied to the remuneration of contributors, to whom would be referred the large collections in zoology already amounting in insecta alone to about 3,000 species. The plants have been determined at the Herbarium of the Royal Gardens, Kew, and are nearly completed to date. A separate report on the collections in zoology and botany is given below.

It is proposed by the Committee to accept the services of Mr. R. V. Sherring, F.L.S., to make collections in botany in the island of Grenada during the coming winter. Mr. Sherring is well acquainted with the West Indies, and has already made collections there and added several new species of ferns to the flora of Jamaica.

Zoology.

Since the last report of the Committee three collections have been received from Mr. H. H. Smith, the collector sent by Mr. Godman to the island of St. Vincent. These collections include a complete set of the birds already known to inhabit the island, and a few additional species; a small number of reptiles and crustaceans; a large series of spiders; and a great many insecta; these last amounting, it is thought, to about 3,000 species.

In 1889 Colonel Feilden paid a visit to the island of Dominica for the purpose of ascertaining whether the Diablotin (*Œstrelata hæsitata*) has become extinct there, as has been reported by Ober. The account of his expedition that Colonel Feilden has published leaves little doubt that this is the case.

Although Mr. Smith has now been occupied about a year and a half in the exploration of the island of St. Vincent, Mr. Godman has decided, with the concurrence of the Committee, that he shall still continue there, as it is not yet clear that the more inaccessible portions of the island have been sufficiently examined.

Mr. Godman has agreed to give a first set of the zoological specimens obtained by his collector to the National Collection contained in the British Museum, and the Committee is at present endeavouring to find competent zoologists to work out the extensive series of insects and spiders that has been obtained.

Commander Markham, R.N., contributed some specimens in zoology collected by him in the Leeward and Windward Islands of the West Indies, and Captain Hellard, R.E., local secretary to the Committee at St. Lucia, has recently forwarded four boxes of *Lepidoptera* collected by him in that island.

Botany.

A small collection of plants, numbering 143 specimens, was received from Mr. J. J. Walsh, R.N. This collection included plants from Dominica, St. Martin's, St. Eustatius, St. Kitts, St. Lucia, and Grenada. Most of the plants consisted of common West Indian species, presumably such as would be met with in the more accessible spots in the various places visited.

The remainder of the plants collected by Mr. Ramage at St. Lucia have been determined. Of 84 species sent 62 have been fully determined. The others include several that are apparently new. They are wholly woody or forest plants, and comprise *Sloanea* sp., *Picramnia* sp., *Zanthoxylum* sp., *Bursera* sp., *Miconia* sp., *Cybianthus* sp., *Lucuma* sp., *Siparuna* sp., *Helosis* sp., *Gymnanthes* sp., and *Cyclanthus* sp. In one or two cases the material is hardly sufficient for satisfactory determination. Two of the above undetermined species have also been collected in Dominica and one in Martinique by earlier collectors.

Three collections have been received from St. Vincent through Mr. Godman, viz., in September 1889, and March and August 1890. The first collection has been determined at Kew by Mr. Rolfe as far as the end of the *Polypetalæ.* Of the 252 numbers (to this point) 47 were duplicates; thus 205 species were represented. All but about 9 of these were fully determined, the great bulk consisting of widely diffused West Indian plants; 128, or more than half, appear to have been recorded from the island before.

The undetermined specimens are *Trattinickia* sp., *Stigmaphyllon* sp., *Trichilia* sp., *Meliosma* sp., *Lysiloma* sp., *Moquilea* sp., a species of *Eugenia* obtained by Hahn in Martinique, and two species probably of *Pithecolobium*, of which the material was somewhat inadequate. Several of these appear to be new, the first-named being specially interesting, because the genus was hitherto only known from Guiana and Brazil. In addition to this may be mentioned that several species of somewhat restricted distribution in the West Indies, more especially from Martinique and St. Lucia, have also been found in St. Vincent.

The second collection from St. Vincent consisted for the most part of ferns. Mr. J. G. Baker has fully worked out these. They include 133 species and well-marked varieties, three of which are new. The specimens are in excellent state of preservation, and it is probable that we have amongst them nearly all the fern flora of the island, both of the mountains and the lowlands.

As our knowledge of the fern flora of St. Vincent may be now regarded as practically exhaustive, it seems probable that some species hitherto attributed to the island, on the authority of specimens collected by the Rev. Lansdowne Guilding, really belong to other islands. This error has arisen from want of precision in exactly localising the specimens, a practice the importance of which was hardly recognised at the time they were collected.

The collections received in August last contain three additional species of ferns, making the total number collected by Messrs. Smith 136. The added species are *Dicksonia cicutaria*, Sw., *Davallia aculeata*, Sw., *Cheilanthes radiata*, R. Br. In addition there are 389 numbers of flowering plants, and 3 palms. These will be determined later.

The Committee would again draw particular attention to the botanical and zoological bibliography of the Lesser Antilles prepared under its direction, and published as an appendix to the Report for 1888. This bibliography has been widely distributed in the West Indies and in Europe, and has proved of considerable service in carrying out the objects for which the Committee was appointed.

The Committee recommend their reappointment, and that a grant of 100*l.* be placed at their disposal.

Report of the Committee, consisting of Dr. P. L. Sclater, Professor Ray Lankester, Professor Cossar Ewart, Professor M. Foster, Mr. A. Sedgwick, Professor A. M. Marshall, *and* Mr. Percy Sladen (*Secretary*), *appointed for the purpose of arranging for the Occupation of a Table at the Zoological Station at Naples.*

Prosperity and advancement have been the keynotes of every Report which your Committee have presented upon the Zoological Station at Naples. The account given this year by Dr. Dohrn is of the most satisfactory character. The annual subvention of 1,500*l.* granted to the Station by the German Parliament for the past ten years has now been increased to 2,000*l.*—a circumstance directly due to the personal interest of the German Emperor. The Directorate is by this means enabled to extend the sphere of action of the Institution in more than one direction, and this without increasing the amount of the annual contribution paid by governments, universities, or learned societies for the use of a Table. The Zoological Station is thus in the advantageous position of now being able to offer even greater facilities than formerly to those who avail themselves of the privilege.

It was stated in the last Report that the Physiological Laboratory was in part completed. Several physiologists have been at work during the past year. Dr. Loeb, of Strasburg, has conducted a series of investigations on heliotropism; Professor Exner, of Vienna, has completed his experiments on the visual phenomena in crustaceans; Dr. Herter is engaged on the chemical analysis of the muscles of the dog-fish and other species of fishes; Professor Einthoren is going to work on the functions of the fish-bladder; and it is expected that before long other physiologists of well-known reputation will be attracted to Naples to begin investigations on a still larger scale in this almost virgin field of research. It is intended to complete the equipment of the physiological laboratory step by step, in accordance with the requirements of workers, and thus leave nothing to be desired in the internal arrangements of the department.

The Morphological Department has not been neglected, and in nearly every possible way the wants of students have been satisfied. Those who worked in the Zoological Station a few years ago would be astonished to see how much greater comfort and how many more facilities are now afforded to microscopists and embryologists than formerly. Nearly every room and table, and especially those in the so-called 'large' laboratory, have benefited greatly from the increased financial means now at the disposal of the Director. It was sometimes felt to be a drawback by those who worked in the large laboratory that they did not obtain the complete seclusion, nor the advantages of the greater number of tables, drawers, and pigeon-holes, enjoyed by those who were fortunate in having a separate room. This inequality has been removed; each worker in the large laboratory is now almost completely separated from the others, and the table surface, as well as the number of drawers and pigeon-holes, placed at the disposal of each worker has been more than doubled. The supply of sea and fresh water has been greatly increased, and gas and other conveniences for work have been provided in such a way as to make each student entirely independent; in fact, a general feeling has been expressed that the Zoological Station is one of the most comfortable of laboratories to work in.

In addition to improving the internal arrangements of the Station, the Direction has extended its command over a wider sea area than formerly, and has also provided more efficient means of obtaining the material requisite for study. In several cases considerable sums of money have been spent in sending out small expeditions to procure a greater number of embryos than could otherwise be obtained when these were needed, in certain stages of development, for the purpose of solving some special problem.

The extraordinary demand for Selachian embryos, and the fact that almost every species has to be studied separately, to enable the morphologist to deal successfully with the question of the phylogeny of vertebrate organisation, render it necessary to find a way of overcoming the difficulty of obtaining dog-fishes and skates at all seasons of the year. It has accordingly been resolved to combine this task with another great undertaking, which has hitherto been deliberately omitted from the programme of the Zoological Station, viz., the investigation of the greater depths of the Mediterranean.

Much has been done in this direction by English and French expeditions, and their work will not improbably be continued by the Prince of Monaco, to whose munificence and investigations science is already indebted for important contributions on the fauna of the Mediterranean. The Zoological Station has refrained hitherto from participating in this field of action, but the time seems now to have arrived for launching out in this new undertaking. Encouraged by the generous co-operation of the Italian naval authorities, and with the support of Admiral Magnaghi, the hydrographer of the navy, a series of investigations will shortly be carried out, from which important results will no doubt be obtained. It is proposed to commence in the spring of next year with the investigation of the greater depths near Capri, where the bottom of the Mediterranean slopes rapidly down to a depth of a thousand metres or more, and where the conditions of the sea-bottom promise to yield interesting faunistic results. It is hardly necessary to remark that the Zoological Station is especially adapted for conducting such a research, with its large number of specialists, its highly developed art of preserving specimens, and its situation so near to the field of operations.

The foregoing particulars will fully show the present high state of efficiency of the Zoological Station, as well as the advances now in progress and in prospect. Dr. Dohrn is to be congratulated on the well-being of the institution which he had the large-mindedness to found and has so ably conducted hitherto.

The Publications of the Station.—The progress of the various works undertaken by the Station is here summarised:—

1. Of the 'Fauna und Flora des Golfes von Neapel' the following monograph has been published since the last Report:—

P. Mayer: 'Nachtrag zu den Capitelliden.'

Monographs by Dr. Falkenberg on 'Rhodomeleæ' and by Dr. Della Valle on 'Gammarini' are in the press (about 50 plates and one-third of the text of the last named being printed).

2. Of the 'Mittheilungen aus der Zoologischen Station zu Neapel,' parts ii. and iii. of vol. ix., with 8 plates, have been published.

3. Of the 'Zoologischer Jahresbericht' the whole 'Bericht' for 1888 has been published.

4. Of the 'Guide to the Aquarium,' a third Italian edition ('Guida dell' Acquario') has been published, combining the former atlas and guide.

Extracts from the General Report of the Zoological Station.—The officers of the Station have courteously furnished lists (1) of the naturalists who have occupied tables since the last report, (2) of the works published during 1889 by naturalists who have worked at the Zoological Station, (3) of the specimens sent out by the Station during the past year. These details are appended.

The British Association Table.—The use of the British Association Table was granted to Mr. Gerard W. Butler, who proceeded to Naples at the beginning of the year, and was still in occupation at the time when this report was sent in. Mr. Butler has furnished an account of his work up to date, from which it will be seen that interesting results may be anticipated when he has been able to work up the large mass of material which he was fortunate in obtaining.

Two applications for permission to use the British Association Table during the current and coming year have been received. The Committee hope the Association will enable them to sanction these and other applications by the renewal of the grant (100*l.*) for the ensuing year. The foregoing details and the undoubted advantage of leasing a table at the Zoological Station fully justify, in the opinion of your Committee, their strongly recommending the renewal of the grant.

I. *Report on the Occupation of the Table, by* Mr. Gerard W. Butler.

I arrived at the Zoological Station on January 22, and having already enjoyed a stay of six months here, and having the offer of a week or two more to finish off my work, would heartily thank the Committee of the British Association for placing the table at my disposal for so long a time. I feel that, apart from any results which I may in the future be able to produce as the definite outcome of my work here, I have obtained a large amount of information, that will be most useful to me as a foundation for future studies, which I either could not have obtained at all, or not nearly so well, had I remained in England. The following report will, I think, confirm this. It will be seen, for instance, that I have been placed in most favourable conditions for studying the development of Elasmobranch fishes, and of Lacerta, and for obtaining a general idea of the fauna (pelagic and other) of a sea such as the Mediterranean. And supposing for the moment that it be possible to draw a definite line between the confirmation of views that exist and the substitution for these of others more or less different, it is obvious that, in weighing the value of a zoological station such as this, the benefit which younger students in particular derive from the former process should not be left out of consideration.

I came here with the intention of studying one or both of the following subjects: (1) the development of the air-bladder of fishes, with special regard to the question of its homologue, if any, in other types; (2) the anatomy and development of the Chelonia.

Turning first to the latter of these subjects, I have been able to dissect three specimens of the turtle (*Thalassochelys corticata*) from the neighbouring sea, which died in the aquarium. Being interested in the question of the subdivision of the body cavity, I was glad to be able to make out the true relations of the peritoneum and the different viscera more clearly than I had previously done from the examination of Emys and Testudo. For instance, the lesser or omental sac of the peritoneum has its relations to the rest of the peritoneal cavity rendered clear by the fact that the two communicate by a well-marked *foramen of Winslow*, which appears not to exist in *Emys* and *Testudo*, where, consequently, the dextro-dorsal lobe of the liver seems to lie in a closed sac. The relations of the spleen were also clear in this type. It is in the usual position, and its proximity to the rectum in some Chelonia has no morphological significance. In *Thalassochelys*, again, the lungs, as in *Testudo*, project but little into the peritoneal cavity.

As to the embryology of the Chelonia, both *Emys* and *Testudo* breed in the neighbourhood of Naples, but it appears to be impossible to find eggs laid by these animals in their natural haunts. I have accordingly procured some thirty or more specimens of *Testudo* for the chance of their depositing the eggs in a small enclosure here at the Zoological Station. It is mainly for this chance that I am now waiting at Naples. The question to which I specially desire an answer is, Are the lungs of *Testudo*, and other Chelonia like it, at one time surrounded by a pleural cavity which, as in birds, becomes afterwards obliterated; or, as seems to me more probable, are they always practically outside and dorsal to the body-cavity?

My work, however, on reptiles has not been confined to the Chelonia. I have been glad since the beginning of the summer to seize the splendid opportunity that Naples affords, and preserve a pretty complete series of embryos of *Lacerta*, and also to obtain a certain number of stages of *Tropidonotus* and other snakes. With this material I hope to be able to clear up certain points in the anatomy of these animals, especially concerning the subdivision of the body cavity and the relations of the 'fat-bodies' to it.

I may here state that, examining at Naples better specimens of *Tropidonotus natrix* than I have before obtained, I find that in this snake (and apparently the conditions are exactly the same in *Elaphis*, and perhaps this is true of many or even all snakes) there is apparently the same transverse division of the body cavity behind the liver, by a *post-hepatic* *septum*, that occurs in birds, crocodiles, and the Teiidæ among lizards (cf. 'Proc. Zool. Soc.' Nov. 19, 1889). In *Tropidonotus* the main abdominal cavity (which, if my description be correct, may contain nothing but the reproductive glands and their ducts, the intestine lying outside it) cannot be traced farther forward than the region where the gall-bladder, spleen, and pancreas are grouped together. This is in the adult at a point some inches behind the posterior extremity of the liver, and corresponds approximately to the point where the reproductive viscera above referred to terminate anteriorly. Between the gall-bladder and the hinder end of the liver I see no trace of the body-cavity. Each lateral half of the liver lies in a separate closed sac, apparently corresponding to the ventral liver-sacs of birds. As to whether the body cavity has, in the region of the liver, any dorsal representative, I am not prepared to speak. In *Tropidonotus* the somewhat sharp transition from the fleshy anterior part of the lung to the thin-walled sac that forms its posterior part, judging from the relation of the lung to the liver and to that part of the body cavity which surrounds it, seems to me to correspond to the transition from the lung proper to the air sacs of birds.

The questions bearing on the structure of snakes that I would make out by the development are: What are the relations of the lung to the body-cavity? How does the constriction of the latter behind the liver come about?

The preceding remarks may serve to remind the reader that the worker at the Zoological Station at Naples need not confine himself to the study of marine organisms.

To turn now to the latter, and first to the question of the air-bladder. This is of course a wide subject, but the question that mainly interests me is this: Regarding the air-bladder of fishes simply as a diverticulum of the alimentary canal, what, if any, homologue has it in either the Elasmobranchs or in the higher animals? Even those who are satisfied with what is, I believe, the accepted view of the majority, that the ventral lung of the higher vertebrata and Dipnoi and the ventral air-bladder of *Polypterus* must in some way correspond to the dorsal air-bladder of the other Ganoids and Teleosteans, will admit that the developmental history of the air-bladder in the various types is at present vague, and that the origin, early history, and relation to each other of the various diverticula of the alimentary canal, considered as such, apart from their ultimate structure and function, are morphological questions of almost primary importance.

As I understand the word it is impossible, by any straining of its meaning, to say that a ventral outgrowth of the alimentary canal in one animal is *homologous* with a dorsal outgrowth in another, unless it can be shown either (1) that one is a later modification of the other, which now arises straight away by an abbreviation of development, or (2) that both are but different modifications of one and the same thing, such, for instance, as a pair of lateral outgrowths like the embryonic gill-pouchings.

My work at Naples, as well as general considerations, lead me to doubt whether any weight is to be attached to the ever-quoted lateral (Albrecht says it is only a little to one side of the mid-dorsal line) opening of the pneumatic duct in *Erythrinus*. I find, for instance, in some of the Syngnathidæ that I have examined, where the embryo seems so stretched over a large mass of yolk as to make it easier for the alimentary canal to send out lateral rather than either dorsal or ventral outgrowths, that as a matter of fact the pneumatic and bile ducts do grow out, one a little to one side of the embryo and the other to the other, a fact which unfortunately renders it impossible to obtain satisfactory median longitudinal sections. Yet in this case inspection convinces us that the deviation has no morphological significance. We may, in fact, perhaps best consider the alimentary canal as slightly twisted in this region, and if this twist became permanent we should have the pneumatic duct opening laterally (supposing it to persist).

For the purpose of studying the question of the air-bladder I have preserved all stages possible of fish of which I could obtain the eggs in sufficient quantities. Of *pelagic eggs* floating freely and separately I obtained eggs of *Labrax lupus* (spawned in the aquarium) at the end of January, and of *Coris Giofredi* (by artificial fertilisation) at the end of May. Obviously suitable for obtaining a series of stages are those eggs which float about connected together by a transparent (albuminous ?) egg case, such as those of *Scorpæna* and *Fierasfer*, obtained in June and July, the latter being apparently rather plentiful. Suitable also are those which are attached by fibrous web-like tissue to seaweeds, as those of *Cristiceps*, of which I obtained a few in April.

Of eggs that are attached side by side to rocks I have obtained those of *Blennius* in July, and a practically unlimited supply of the eggs of certain species of *Gobius*, such as *G. paganellus*, and another with eggs resembling those of *G. niger*. *G. capito* was also plentiful, and there was a fourth of which I had a few. Finally a rich and obviously convenient source of material has been the Syngnathidæ. In the spring months, February to May, there was a plentiful supply of *Syngnathus* (various species), *Siphonostoma*, and *Nerophis*, and in the summer months of June and July these were replaced by *Hippocampus*, also very numerous.

I have already cut a large number of sections from this material for various purposes, but as yet only part of the above types have been so treated. It is not, therefore, surprising that I have no conclusion at present to state as regards the air-bladder, especially as what I have as yet seen of the development of the alimentary canal of Teleosteans and Elasmobranchs, together with what I have read, has strongly suggested to me a line of enquiry which is new, the value of which, therefore, requires to be tested by the study of other types. When I have received eggs in the earliest stage I have, of course, been glad to be able to follow the development throughout, and have, in some cases, preserved a series of stages from the beginning. I became rather interested in the early stages of segmentation. Most of the eggs of *Syngnathus* that I received of this age were either dead or died soon after removal from the pouch, but I was able to watch the early segmentation processes in *Coris Giofredi* and repeatedly in *Gobius paganellus* and another species of *Gobius* (perhaps *G. niger*, perhaps *G. jozo*) which I will call *Gobius b.*, in accordance with the label in my series. This last species specially interested me. There is here a very small proportion of yolk for a Teleostean egg, less apparently than in *G. paganellus.*

In the case of this *Gobius b.* the first four segmentations (*i.e.*, the stages until the egg is divided more or less completely into sixteen) exactly correspond to the first four segmentations in the frog as usually described. Thus the first two segmentation planes are vertical, the third horizontal, and the fourth vertical and bisecting the angle between the first two.

This is the only Teleostean, so far as I am aware, in which the true nature of the third segmentation process can appear. It is masked, for instance, even in *G. paganellus*, though this latter species is very instructive in the light of *Gobius b.* as affording a passage from the regular or amphibian type of segmentation visible in this last to the types that obtain in other Teleosteans. If we observe a number of eggs of *Gobius paganellus* that have undergone their third segmentation we can find some that resemble these of *Gobius b.* but for the fact that the four protoplasmic swellings on the surface of the yolk that represent the four lower cells have been, as it were, forced apart, two to one side and two to the other of the square of four cells that form the upper half of the egg; and, on the other hand, other eggs will show us the eight divisions arranged in the two rows of four, which seems the most common form with Teleosteans of this stage.

Much ingenuity has been expended in explaining the third segmentation process in individual species of Teleosteans. However, a comparison of what I have been able to see for myself and what I have read makes me think that these early segmentation processes in Teleosteans can be best and most consistently explained as due to a masking of the simple regular geometrical plan of, for instance, *Amphioxus* and the frog by the presence of a greater or less amount of food yolk, and that all attempts to explain the plane of the third segmentation more definitely than by saying that it is *trying to be horizontal*, and to separate four less yolky cells from the other yolk-laden and imperfectly divided part of the egg, will be unsatisfactory, as wanting generality and only explaining what occurs in particular cases.

After I had studied the segmentation in these species of *Gobius* I discovered Rauber's paper ('Neue Grundlegungen zur Kenntniss der Zelle,' *Morph. Jahrb.* 1883), part of which happens to be devoted to a comparison of the early segmentation stages in *Rana* and a species of *Gobius*. As, however, Rauber was not fortunate enough to examine the species of the latter that fell to my lot, he has, as I think, missed the real and simple solution that they might have indicated, viz. that here, as in so many other cases in comparative embryology, it is the different amount of yolk in the eggs which causes processes that are really essentially the same to appear so very different.

I have been able during the last month to examine the complicated structure of the floating egg-case of *Fierasfer acus*, briefly described at p. 68 of the monograph on this genus in the Naples 'Fauna und Flora.' Shortly, this consists of an aggregate of hexagonal tubes, like elongated bee cells, open at both ends and grouped symmetrically side by side, so as to form an oval hollowed out at one side, on which and on the opposite side the tubes open. Each of these prismatic cells has a number of eggs attached to its internal walls by short stalks. To make out the whole structure it is best both to examine in the natural state and to coagulate the egg-case with alcohol. Corrosive sublimate causes the whole case to disappear, and Perenyi's fluid is not good. The egg-case seems also to disappear shortly before hatching. I hope to be able to examine the egg-case of *Scorpæna* more carefully. This is considerably larger than that of *Fierasfer*, and appears to consist of a single large sac to the inner wall of which the eggs are attached, but I have not yet been able to verify this from a hardened preparation. It would apparently be interesting to make a comparative study of the various modes in which Teleostean eggs are attached either to fixed foreign bodies, or to the male parents, or to each other by a more or less complicated transparent enveloping mass, and to see whether the attaching tissues in the different types are really different, or merely different modifications of an essentially similar secretion.

Passing now from the Teleosteans, it is unnecessary to state how gladly I seized the opportunity here afforded me of studying the development of the Elasmobranchs. I might say of *Pristiurus melanostomus*, for though I have obtained a few embryos of *Torpedo marmoratus* (mostly fairly advanced, with long external gill filaments) I have not yet examined these by sections, so that my work has been practically confined to the former type, of whose eggs I have received during my stay here a large number, notwithstanding the great demand there has been for this material from numerous other quarters; for this most graceful little dog-fish has, by reason of the diagrammatic simplicity of its development, the mournful satisfaction of being one of the biologists' classic animals.

The laid eggs, it appears, are never found, but the early stages can be obtained from the air-ducts throughout the year, and, as is known, these develop well if removed and placed in a tank where the sea water is slowly and constantly changed. It should be noted, however, that while from January to the end of April I had practically no mortality among my eggs, as the warmer weather came on the death rate became considerable, and the conservator, Sig. Lobianco, informs me that his more extensive experience confirms this. Again, the development of this fish is slow, *Pristiurus*, according to the above-mentioned authority, being about seven months old when hatched, so that, as none but the youngsters can be obtained by the fisherman, it requires time to rear the older ones.

I have been fortunate enough to obtain a continuity of stages from A to O of Balfour, or from the first appearance of the segmentation cavity in the blastoderm to the time when the embryo is about an inch and a half in length, with long external gill filaments. From this material I cut and mounted, as soon as possible, a set of complete series of sections to guide me in my work. I have already found them very interesting and instructive, and have reason to expect that they will be of great use in the future.

Something may be said as to the methods I employed. The eggs of *Pristiurus* are, of course, only semitransparent, but by a proper adjustment of the light one can follow through the shell, using both reflected and transmitted light, all the changes in the blastoderm and embryo, such as the extension of the former over the yolk, and the origin and subsequent behaviour of the segmentation cavity, and the slow growth of the young fish. For examination of the living egg by reflected light, *i.e.*, viewing the blastoderm and embryo as opaque objects, sunlight, or even diffused daylight, may do; but for inspection as transparencies by transmitted light I could find nothing better than a simple candle flame held behind the egg, daylight, if present, being more or less screened off as necessary.

As soon, then, as I received eggs of *Pristiurus* I sketched each blastoderm, and embryo if it had developed, as above described, and placed each egg by itself in a shallow glass vessel with a distinguishing number, this again being placed in one of the tanks of circulating water. The sketching process was afterwards repeated, in the earlier stages daily and later at longer intervals. Perhaps *Pristiurus* is the only vertebrate (the shell of *Scyllium* would be too opaque) whose embryonic development can be followed in the same individual so easily and satisfactorily. The slowness of development ensures us not missing anything we want, without the inconvenience of prolonged or all-night sittings. I thus followed one animal for over two months, when he succumbed, probably to the hot weather. This period began a week before the embryo made its appearance on the blastoderm, and at the end all the gills were represented (stages A to K of Balfour).

This plan is not merely interesting, it is useful in two ways. It enables one to know with some precision when to open an egg for any particular stage; and secondly, we thus learn some things that we cannot any other way. Balfour, for instance, more than once refers to the segmentation cavity as first appearing towards the non-embryonic end of the blastoderm, and to a preliminary thickening occurring towards the embryonic end.[1] Now this is certainly the view one would be led to adopt, without some systematic observation of the same blastoderm by transmitted light at daily intervals. There is a swelling towards the opposite end of the blastoderm to that at which the segmentation cavity arises, but this does not come to anything, and the segmentation cavity, so to speak, travels as it increases in size from the end at which it first appeared towards the other. At least although the behaviour of the segmentation cavity varies, sometimes spreading from one end over the whole blastoderm, the above is what often occurs, and this change of position is the explanation of Balfour's statement, the main point being that, whatever variation there may be, the embryo always appears at the end of the blastoderm at which the first trace of the segmentation cavity had previously been observed.

I would again use a reference to Balfour to give weight to my next remark as to the method of preserving blastoderms prior to or just about the time of the first appearance of the embryo. Balfour says,[2] 'The shape of the blastoderm in hardened specimens is not to be relied upon, owing to the traction which the blastoderm undergoes during the process of removing the yolk from the egg shell.' Now the method recommended is this: Do not remove the yolk from the egg shell, but carefully holding the egg with its broadest section horizontal, and having made sure that the blastoderm is turned to the uppermost side of the yolk, cut away the overlying side of the shell, and then, using the fingers, not forceps, place the egg carefully in Kleinenberg's picro-sulphuric acid and follow Balfour's instructions for the chick. Leave the egg for four or five hours in Kleinenberg, then with all care replace this by alcohol of 30 per cent. to wash, and this again by 50 per cent. for one hour, and only after the egg has been in this for the whole or part of the time attempt to cut round the blastoderm. We are thus enabled to remove the blastoderm preserved flat and undistorted and in its natural relations to the underlying yolk, a greater or less thickness of which can be removed with it, according as the alcohol has acted a longer or shorter time. It must have been the non-adoption of some such method as this, coupled with the fact that the microtomes of that time did not, I believe, give facilities for making complete series of sections which are so desirable, that prevented Balfour from ascertaining the very interesting fact (a fact for which he was obviously on the look-out), first hinted at by Rückert[3] in *Torpedo*, and described for *Pristiurus* a few months ago by

[1] *Elasm. Fishes*, pp. 26, 33, 34, 44, 46, 54. [2] *Op. cit.* p. 71.

[3] 'Ueber die Anlage des mittleren Keimblattes und die erste Blutbildung bei Torpedo,' *Anat. Anz.* 1887.

Rabl, that in these typical vertebrates the mesoderm, as in *Amphioxus* and various lower animals, arises by what must be considered paired pouchings of the hypoblast (1) of the archenteron, (2) of the lip of the blastopore. I was much interested in being able to independently confirm this fact for *Pristiurus* before I knew of the above-mentioned papers.

In *Pristiurus* the *segmental duct* as described by the later writers on Elasmobranchs, and as is the case in so many of the higher vertebrates, appears to arise almost if not entirely from the epiblast.

Being at Naples, where *Amphioxus* is so plentiful, I naturally desired if possible to see something of its development; but, though I had a large supply of the animals, I was unsuccessful, probably because, having other work on hand, I did not devote sufficient care to them, for another student was more fortunate. However, by mixing a quantity of their ova and spermatozoa, when naturally fertilised eggs seemed unattainable, I made a very small percentage of eggs go through the earlier stages of segmentation. One or two of these eggs were interesting in that, from whatever cause, the process went on abnormally, segmentation being partial, as in a Teleostean.

Turning, lastly, to the invertebrata, I had little time to examine, and have little space to describe, the wonders of the 'Auftrieb,' or product of surface-skimming, supplied to me daily, with its swarms of copepods and other crustacea, especially the larvæ, with its salpæ and medusæ, pteropods, ctenophores, appendicularíæ and larvæ of worms, echinoderms, and other animals, and above all the beautiful compound hydrozoa. I was very glad to be able to see alive and at close quarters many animals that I had either never seen before or only as preserved specimens, and the occasional trips in the 'Johannes Müller' afforded opportunities for seeing these in their natural home, as well as for getting an idea of the life at the bottom.

It may be worth while to mention a point of which I have seen no description with regard to a species of *Lima* that occurs here. This has the power of progressing by jumps like a *Pecten*. Three specimens, however, that I have kept for some time, partly in a round glass beaker and partly in a large tank about two feet square, in both cases with circulating water, have each made for themselves what I can only describe as a house or tent, by closing in with a fairly dense network of byssus-like material some corner of the tank or a portion of the bottom of the beaker. Within this house the animal itself is free to move. In more than one case I have made the animal repeat this process, but have not been able to catch it in the act of spinning. Does the *Lima* do this to protect itself against foes or from being moved by currents of water, or is the byssus net to catch food, or are all these ends attained?

Lastly, it is hardly necessary for me to express an opinion on the structure and function of the Zoological Station, but it certainly is a great boon to have adjoining the room in which one's work-table is situated another room which, while of moderate size, contains practically every work, periodical or other, that the biologist can require, and where the smallest pamphlet is clearly catalogued as soon as received. In fact, after all that has previously been said by more competent judges as to the admirable intelligence and precision with which the Station is worked throughout every department, I have only to thank the staff and all the workers therein for the ready kindness and civility that I have met with during my pleasant stay at Naples.

II. *A List of Naturalists who have worked at the Zoological Station from the end of June* 1889 *to the end of June* 1890.

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
506	Prof. A. Della Valle .	Italy	July 1, 1889	Nov. 4, 1889
507	Mr. Arthur Willey .	British Association .	„ 14, „	Aug. 2, „
508	Prof. C. Emery . .	Italy	„ 19, „	Oct. 12, „
509	Dr. A. Pasquale . .	„	„ 19, „	—
510	Dr. d'Abundo . .	„	Aug. 2, „	Sept. 2, „
511	Prof. F. Steiner . .	Baden	„ 7, „	„ 1, „
512	Dr. F. S. Monticelli .	Italy	„ 1, „	—
513	Sr. José Gogorza .	Spain	„ 16, „	—
514	Teniente Borja de Goyeneche	„	„ 17, „	—
515	Stud. A. Tosi . .	Italy	„ 17, „	„ 29, „
516	Dr. H. Rex . .	Austria . . .	Sept. 6, „	Nov. 22, „
517	Prof. C. Grobben .	„	„ 9, „	Sept. 29, „
518	Dr. G. W. Müller .	Prussia . . .	„ 25, „	June 29, 1890
519	Mr. W. W. Norman .	Hamburg . .	Oct. 5, „	Mar. 21, „
520	Mr. T. Groom . .	Cambridge . .	„ 9, „	May 30, „
521	Dr. J. Loeb . .	Strasburg . .	„ 10, „	„ 1, „
522	Dr. K. Endriss . .	Würtemberg . .	„ 13, „	Mar. 20, „
523	Dr. H. Trautzsch .	Saxony . . .	„ 13, „	Feb. 15, „
524	Dr. G. Magini . .	Italy	„ 13, „	Oct. 19, 1889
525	Dr. B. Friedländer .	Prussia . . .	„ 14, „	Nov. 25, „
526	Dr. P. Davignon .	Russia . . .	„ 28, „	Apr. 10, 1890
527	Prof. A. Kowalewski .	„	Nov. 7, „	May 13, „
528	Dr. E. Weber . .	Switzerland . .	„ 7, „	Mar. 17, „
529	Dr. Köppen . .	Russia . . .	„ 7, „	Feb. 7, „
530	Teniente J. Anglada y Rava	Spain . . .	„ 24, „	—
531	Prof. O. Nüsslin .	Baden	„ 26, „	Apr. 22, „
532	Dr. E. Vanhöffen .	Prussia . . .	Dec. 1, „	June 1, „
533	Dr. R. Schneider .	„	„ 30, „	Apr. 7, „
534	Dr. G. Jatta . .	Italy	Jan. 1, 1890	—
535	Dr. F. Raffaele . .	„	„ 1, „	—
536	Dr. P. Mingazzini .	„	„ 1, „	—
537	Dr. S. Pansini . .	„	„ 1, „	—
538	Dr. G. Cano . .	„	„ 1, „	—
539	Dr. P. P. C. Hoek .	Holland . . .	„ 7, „	Mar. 21, „
540	Mr. G. W. Butler .	British Association .	„ 21, „	—
541	Prof. H. Ambronn .	Saxony . . .	Feb. 12, „	June 10, „
542	Mr. H. B. Ward .	Baden	Mar. 7, „	Apr. 8, „
543	Dr. F. Schütt . .	Hamburg . .	„ 8, „	„ 23, „
544	Prof. H. Ludwig .	Prussia . . .	„ 10, „	„ 19, „
545	Prof. F. Zschokke .	Switzerland . .	„ 15, „	„ 10, „
546	Prof. S. Exner . .	Austria . . .	„ 17, „	„ 23, „
547	Prof. O. Bütschli .	Baden	„ 18, „	„ 21, „
548	Prof. C. Rabl . .	Austria . . .	„ 19, „	„ 12, „
549	Prof. J. van Rees .	Holland . . .	Apr. 5, „	June 10, „
550	Prof. Knoll . .	Austria . . .	„ 6, „	May 10, „
551	Dr. J. Vosseler . .	Würtemberg . .	„ 12, „	June 10, „
552	Dr. J. Rückert . .	Bavaria . . .	„ 18, „	May 21, „
553	Dr. B. Lvoff . .	Russia . . .	„ 28, „	June 27, „
554	Prof. S. Apáthy . .	Hungary . . .	May 24, „	—
555	Prof. G. von Koch .	Hesse	„ 28, „	—
556	Dr. P. Cerfontaine .	Belgium . . .	June 9, „	—
557	Dr. M. Mendthal .	Prussia . . .	„ 11, „	—
558	Dr. A. Coggi . .	Italy	„ 13, „	—

III. *A List of Papers which have been published in the year* 1889 *by the Naturalists who have occupied Tables at the Zoological Station.*

Prof. V. Graber . .	Ueber die Empfindlichkeit einiger Meerthiere gegen Riechstoffe. 'Biol. Centralblatt,' 8. Bd. 1889.
Dr. F. Sanfelice . .	Ricerche batteriologiche delle Acque del Mare. 'Boll. Soc. Nat. in Napoli,' anno 3, 1889.
,, . .	Dell' uso dell' Iodo nella Colorazione dei Tessuti con la Ematossilina. *Ibid.*
,, . .	Intorno all' Appendice digitiforme dei Selaci. *Ibid.*
,, . .	Dell' uso della Ematossilina, etc. *Ibid.*
Dr. F. Raffaele . .	Metamorfosi del Lepidopus caudatus. *Ibid.*
,, . .	Note intorno alle specie mediterranee del genere Scopelus. 'Mitth. Zool. Station, Neapel,' Bd. 9, 1889.
Dr. F. A. F. C. Went .	Die Vacuolen in den Fortpflanzungszellen der Algen. 'Botanische Zeitung,' 47. Jgg. 1889.
,, ,, .	Les modes de Reproduction du Codium tormentosum. 'Kruidk. Archief.' ser. 2, v. 1889.
Prof. de Giaxa . .	Ueber das Verhalten einiger pathogener Mikroorganismen im Meerwasser. 'Zeitschr. für Hygiene,' Bd. 6, 1889.
Dr. R. Semon . .	Ueber den Zweck der Ausscheidung von freier Schwefelsäure bei Meeresschnecken. 'Biol. Centralblatt,' 9. Bd. 1889.
Dr. J. Thiele . . .	Die abdominalen Sinnesorgane der Lamellibranchier. 'Zeitschr. für wiss. Zoologie,' Bd. 48, 1889.
Dr. P. Mingazzini . .	Ricerche sul canale digerente delle larve dei Lamellicorni fitofagi. 'Mitth. Zool. Station, Neapel,' Bd. 9, 1889.
,, ,, . .	Ricerche sul canale digerente dei Lamellicorni fitofagi. Insetti perfetti. *Ibid.* Prelim. communication in 'Boll. Soc. Nat. in Napoli,' vol. iii. 1889.
,, ,, . .	Ricerche sulla struttura dell' ipodermide nella Periplaneta orientalis. 'Atti Accad. Lincei, Rend.' (4), vol. 5, 1889.
,, ,, . .	Contributo alla conoscenza della fibra muscolare striata. 'Anat. Anzeiger,' 4. Jgg. 1889.
Dr. G. Jatta . . .	Elenco dei Cefalopodi della 'Vettor Pisani.' 'Boll. Soc. Nat. Napoli,' anno 3, 1889.
,, . . .	La innervazione delle braccia dei Cefalopodi. *Ibid.*
Dr. M. v. Davidoff . .	Untersuch. zur Entwicklungs-Geschichte der Distaplia magnilarva, Della Valle, einer zusammengesetzten Ascidie. 'Mitth. Zool. Station, Neapel,' Bd. 9, 1889.
Prof. A. Della Valle .	Sopra le Glandole glutinifere e sopra gli occhi degli Ampeliscidi del Golfo di Napoli. 'Atti Soc. Natural. Modena' (3), vol. iii. 1888.
,, ,, . .	Deposizione, fecondazione e segmentazione delle uova del Gammarus pulex. *Ibid.* 1889.
,, ,, . .	Intorno agli organi di escrezione di alcuni Gammarini. 'Boll. Soc. Nat. Napoli,' anno 3, 1889.
Dr. G. C. J. Vosmaer .	Verslag van de werkzaamheden, etc., aan de Nederlandsche werktafel in het Zoologisch Station te Napels verricht, November 1888–Januari 1889.
Prof. S. Apáthy . .	Nachträge zur Celloidintechnik. 'Zeitschr. wiss. Mikroskopie,' 1888.
,, . .	Untersuchungen über Entwicklungsgeschichte der Hirudineen, 1889. (Hungarian.)
,, . .	Nach welchen Richtungen hin soll die Nervenlehre reformirt werden? 'Biol. Centralbl.' Bd. 9, 1889.
Dr. G. W. Müller . .	Die Spermatogenese der Ostracoden. 'Zool. Jahrb. Morphol. Abth.' Bd. 3, 1889.
Dr. A. Ostroumoff . .	Ueber die Froriep'schen Ganglien bei Selachiern. 'Zool. Anz.' 1889.

Dr. A. Ostroumoff . .	Ueber den Blastoporus und den Schwanzdarm bei Eidechsen und Selachiern. *Ibid.*
Dr. C. de Bruyne . .	De quelques organismes inférieurs nouveaux. Comm. préliminaire. 'Bull. Acad. Roy. Sc., etc., de Belgique,' t. 18, 1889.
Dr. E. Pergens . .	Deux nouveaux types de Bryozoaires cténostomes. 'Ann. de la Soc. Roy. Malac. de Belgique,' t. 23, 1889.
" . .	Untersuchungen an Seebryozoen. 'Zool. Anz.' 1889.
Dr. B. Friedländer . .	Ueber die markhaltigen Nervenfasern und Neurochorde der Crustaceen und Anneliden. 'Mitth. Zool. Station, Neapel,' Bd. 9, 1889.
Dr. L. Savastano . .	Il Bacillo della Tuberculosi dell' Olivo. 'Rendic. della R. Accademia dei Lincei,' vol. v. 1889.
Prof. C. Rabl . . .	Theorie des Mesoderms. 'Morphol. Jahrbuch,' Bd. 15, 1889.
Prof. H. Virchow . .	Ueber die Augengefässe der Selachier, etc. 'Verh. Physiol. Ges. Berlin,' Jgg. 1889–90, No. 1.
" . .	Ueber die Spritzlochkieme der Selachier. *Ibid.*
Dr. O. Lubarsch . .	Ueber die bakterienvernichtenden Eigenschaften des Blutes und ihre Beziehungen zur Immunität. 'Centralbl. für Bakteriologie und Parasitenkunde,' Bd. 6, 1889.
Dr. G. Cano . . .	Viaggio della R. Corvetta 'Vettor Pissani' attorno al globo. Crostacei, Brachiuri ed Anomuri. 'Boll. Soc. Nat. Napoli,' anno 3, 1889.
Dr. C. Hartlaub . .	Ueber die Claparède'sche 'Eleutheria.' 'Zool. Anz.' 1889.
Dr. J. M. Janse . .	Die Bewegungen des Protoplasma von Caulerpa prolifera. 'Pringsheim's Jahrb. für wiss. Botanik,' Bd. 21, 1889.
Prof. G. v. Koch . .	Die Antipathiden des Golfes von Neapel. 'Mitth. Zool. Station, Neapel,' Bd. 9, 1889.

IV. *A List of Naturalists, &c., to whom Specimens have been sent from the end of June* 1889 *to the end of June* 1890.

					Lire c.
1889.	July	7	Mr. W. Schlüter, Halle a/S. .	Collection . . .	125·75
	"	"	K. Industrie, etc., Schule, Mülhausen i/E.	Collection . . .	375·
	"	8	Prof. G. Vimercati, Florence .	Various . . .	34·25
	"	"	Prof. A. Vayssière, Marseilles .	Pleurobranchea . .	7·55
	"	12	Mme. Vimont, Paris . . .	Eggs of Cephalopoda .	19·15
	"	16	Anatom. Inst., Freiburg i/B. .	Dog-fish . . .	24·
	"	"	André et Lieutieur, Marseilles	Phoronis . . .	2·65
	"	25	Gymnasium, Worms . . .	Collection . . .	157·55
	"	"	Public Museum, Milwaukee .	Various . . .	24·45
	"	"	Mr. G. Schlatter, Catania . .	Various . . .	32·20
	"	26	Zoolog. Institute, Halle a/S. .	Various . . .	55·20
	"	31	Mr. W. Schlüter, Halle a/S. .	Collection . . .	55·75
	Aug.	4	Morphological Laboratory, Cambridge	Amphioxus, Ciona .	223·50
	"	"	Cabinet of Comp. Anatomy, Moscow	Squatina . . .	35·50
	"	5	Botanic Garden, Oxford . .	Algæ	37·75
	"	"	Prof. Jeffrey Parker, Dunedin .	Polygordius . . .	—
	"	8	Dr. M. Peracca, Turin . .	Elaphis . . .	45·
	"	12	Mr. A. Skrébitzky, Prelaz-Lausanne	Collection . . .	300·
	"	13	Indian Museum, Calcutta . .	Siphonophora, various .	42·70
	"	17	Museum of Natural History, Stockholm	Fishes	87·15
	"	19	Mr. T. Bolton, Birmingham .	Amphioxus . . .	14·15
	"	20	Phys. Mem. Inst., Strasburg .	Mantle of Ciona . .	58·75
	"	"	Prof. M. Braun, Rostock . .	Worms . . .	—
	"	"	Fourth Higher Middle School, Kanazawa, Japan	Collection . . .	291·50

					Lire c.
1889.	Aug.	28	Mr. W. Schlatter, Catania	Various	48·20
	„	„	R. Museo di Fisica, etc., Florence	Peneus	13·35
	Sept.	13	Zootom. Institute, Warsaw	Embryos of Pristiurus	20·10
	„	14	University College, London	Various	15·15
	„	15	Dr. H. Driesch, Bonn	Pennaria	7·05
	„	24	Musée Royal d'Hist. Nat., Brussels	Collection	931·
	„	„	Veter. Institute, Dorpat	Collection	248·95
	„	„	Mr. J. Chalon, Namur	Elaphis	10·
	Oct.	2	Mr. W. Schlüter, Halle a/S.	Collection	132·90
	„	5	Dr. B. Rawitz, Berlin	Various	125·30
	„	7	Mr. W. Vogel, Magdeburg	Shells	66·25
	„	8	Mr. H. V. Tebbs, London	Collection	67·40
	„	„	Mr. E. Halkyard, Knutsford	Foraminifera	25·
	„	14	Zool. Instit., Berlin	Various	81·45
	„	„	Museum of Natural History, Hamburg	Collection	487·55
	„	17	Dr. F. Keibel, Freiburg i/B.	Embryos of Selachians	38·95
	„	„	Prof. Ciaccio, Bologna	Embryos of Selachians	13·70
	„	18	Dr. Prenant, Nancy	Embryos of Selachians	10·85
	„	26	Calderoni & Co., Budapest	Various	155·55
	„	„	Mme. Vimont, Paris	Siphonophora	25·55
	Nov.	7	Zool. Museum, Naples	Collection	309·70
	„	„	Dr. Edinger, Frankfort a/M.	Embryos of Scyllium, Torpedo	19·40
	„	„	Dr. E. Gaupp, Breslau	Embryos of Pristiurus	15·10
	„	10	Zool. Laboratory, Catania	Various	74·
	„	„	Dr. Barrois, Lille	Pinnotheres	—
	„	„	Mr. V. Fric, Prague	Various	47·75
	„	„	Dr. G. Frank, Wiesbaden	White Rats	—
	„	15	Yorkshire College, Leeds	Amphioxus	25·10
	„	„	Mr. T. Bolton, Birmingham	Amphioxus	86·60
	„	„	University of Colorado, Boulder	Collection	440·70
	„	21	Zool. Museum, Siena	Collection	168·70
	„	„	Cab. of Histology, Rome	Brains of Dog-fish	22·05
	„	„	Lab. d'Anatomie, Geneva	Amphioxus	7·55
	„	„	Accademia dei Fisiocritici, Siena	Protozoa	8·
	„	„	Dr. F. Zschokke, Bâle	Carcinas, Squilla	6·05
	„	27	Zool. Inst., Zürich	Collection	256·45
	„	„	Zool. Museum, Bologna	Embryos of Torpedo	14·75
	„	30	Prof. d'Oliveira, Coimbra	Collection	168·25
	Dec.	2	Università Libera, Perugia	Various	13·85
	„	„	Staatsgymnasium, Heruals	Various	48·45
	„	8	Mr. F. Heydrick, Langensalza	Algæ	9·20
	„	„	Dr. H. Fowler, Plymouth	Isopoda	9·40
	„	9	Dr. L. Eger, Vienna	Labrus	7·
	„	10	Dr. M. Peracca, Turin	Lacerta	14·
	„	20	Mr. H. Bernard, Jena	Asterina, Palmipes	8·15
	„	14	Zool. Staatssammlung, Munich	Collection	715·85
	„	20	Lab. d'Anatomie, Lausanne	Siphonoph., Echinod.	86·45
	„	„	Zool. Lab., University, Edinburgh	Notomastus	4·20
	„	„	Zool. Lab., University College, London	Bourgainvillia	9·40
	„	28	Faculté de Méd., Lille	Tristomum	—
	„	30	Zool. Museum, Modena	Brains of Dog-fish	15·
1890.	Jan.	7	Calderoni & Co., Budapest	Collection	133·15
	„	„	Zool. Cabinet, University, Warsaw	Collection	243·05
	„	„	Morphological Laboratory, Cambridge	Scorpions	29·95

					Lire c.
1890.	Jan.	7	Zool. Inst., Berlin . . .	Arca	9·55
	„	9	Oberrealschule, Sechshaus .	Collection . . .	98·85
	„	17	Paravia & Co., Rome . .	Collection . . .	139·90
	„	15	Prof. Wood Mason, Calcutta .	Peneus, Sicyonia . .	9·50
	„	„	Natural History Museum, Nottingham	Amphioxus . . .	9·95
	„	23	Zool. Museum, Palermo . .	Collection . . .	800·
	„	„	Zool. Inst. Freiburg i/B. . .	Various . . .	147·
	„	25	Anatom. Inst., Groningen. .	Embryos of Dog-fish .	27·65
	„	„	Prof. G. Vimeriati, Florence .	Various . . .	75·15
	„	„	Dr. P. Pelseneer, Ghent . .	Mollusca . . .	15·40
	„	„	Zool. Museum, Bologna . .	Embryos of Lacerta .	6·85
	„	„	Mr. Gwatkin, Cambridge . .	Mollusca . . .	8·60
	„	„	Zool. Inst., Vienna . . .	Aplysia . . .	7·05
	Feb.	6	Mason College, Birmingham .	Collection . . .	273·50
	„	12	Prof. Kunnamoto, Yamaguchi, Kōtō Chūgakkō, Japan	Collection . . .	441·60
	„	„	Zoolog. Institute, Königsberg .	Heads of Dog-fish .	33·70
	„	„	University, Sydney . . .	Siphonophora . .	131·
	„	18	Dr. E. J. Weber, Geneva . .	Collection . . .	585·55
	„	„	Morphological Laboratory, Cambridge	Julus	19·20
	„	21	Académie de Nancy . . .	Ophiactis . . .	4·55
	„	„	Vassar College, Poughkeepsie .	Collection . . .	598·80
	„	26	Univ. College, Aberystwith .	Various . . .	78·45
	„	„	Prof. J. Cohn, Breslau . .	Caulerpa . . .	4·
	March	1	Zool. Museum, Perugia . .	Pecten . . .	4·45
	„	2	High School for Girls, Swansea	Collection . . .	114·10
	„	„	Zool. Lab., Univ., Edinburgh .	Torpedo . . .	18·
	„	4	Durham College of Science, Newcastle-on-Tyne	Amphioxus . . .	11·95
	„	7	Prof. d'Oliveira, Coimbra . .	Collection . . .	195·65
	„	9	Anatom. Inst., Freiburg i/B. .	Torpedo . . .	15·
	„	12	Dr. C. Hartlaub, Göttingen .	Placellophora . .	8·25
	„	13	Luco Cirillo, Naples . . .	Collection . . .	171·35
	„	17	Dr. P. Davignon, St. Petersburg	Collection . . .	143·65
	„	20	Zool. Museum, Munich . .	Mustelus Raja . .	18·50
	„	22	Zool. Museum, Naples . .	Gobius . . .	15·
	„	31	Museum of Natural History, Hamburg	Collection . . .	667·05
	„	„	Mr. W. W. Norman, Indiana .	Fishes . . .	25·
	„	„	Mr. C. Schreiber, Würzburg .	Julus terrestris . .	7·25
	„	„	Prof. K. Kraepelin, Hamburg .	. . . .	15·
	April	4	Landesrealschule, Waidhofen .	Collection . . .	43·55
	„	„	Mr. S. Brogi, Siena . . .	Olindias . . .	9·80
	„	„	Mr. E. H. Butler, London .	Amphioxus . . .	14·50
	„	5	Mme. Vimont, Paris . . .	Torpedo . . .	24·75
	„	9	Dr. M. Sulzer, Bâle . . .	Various . . .	25·
	„	„	Mr. W. Schlüter, Halle a/S. .	Various . . .	36·25
	„	12	Zoolog. Museum, Bologna .	Embryos of Torpedo .	12·
	„	19	University of Minnesota, Minneapolis	Collection . . .	1457·30
	„	„	Zootom. Inst., Warsaw . .	Embr. of Petromyzon .	11·15
	„	23	Zoolog. Sammlung, Zürich .	Various . . .	87·55
	„	„	Zoolog. Laborat., Zürich . .	Collection . . .	288·55
	„	26	Zoolog. Museum, Karlsruhe .	Collection . . .	273·85
	„	„	Zoolog. Inst., Heidelberg . .	Collection . . .	217·95
	„	30	R. Liceo, Messina . . .	Collection . . .	198·
	May	6	Queen's College, Belfast . .	Amphioxus, Corallium	45·30
	„	„	Mr. S. Brogi, Siena . . .	Anemonia . . .	8·25
	„	„	Zoolog. Laborat., University College, London	Various . . .	—

					Lire c.
1890.	May	7	Zoolog. Inst., Prof. Fritsch, Prague	Heptanchus . .	17·
	„	„	Indian Museum, Calcutta . .	Balanoglossus . .	2·15
	„	„	Mr. Nicholson, London . .	Amphioxus . . .	4·75
	„	9	Mr. Schumann, Berlin . .	Shells	18·75
	„	12	Académie, Nancy . . .	Echinoderms . .	6·20
	„	13	Dr. Killian, Freiburg i/B . .	Embryos of Selachians	23·20
	„	„	Baron S. Joseph, Paris . .	Annelids . . .	22·10
	„	„	Zoolog. Instit., Munich . .	Amphioxus . . .	3·
	„	„	Univ. College, London . .	Astroides . . .	7·05
	„	20	Amherst College, Amherst .	Collection . . .	261·
	„	„	Williston Seminary, East-hampton	Collection . . .	153·
	„	„	Mr. Godet, Neuchâtel . .	Various . . .	97·50
	„	„	Mr. Mauler, Neuchâtel . .	Various . . .	65·55
	„	„	Académie, Neuchâtel . .	Collection . . .	193·90
	„	„	Anatom. Instit., Munich . .	Stages of Petromyzon.	50·
	„	„	Prof. Rüdinger, Munich . .	„ „ „	15·
	„	21	Zoolog. Inst., Munich . .	Amphioxus . . .	13·50
	„	23	Marine Biol. Station, Plymouth	Solea	11·85
	„	28	Rev. A. M. Norman, Burnmoor Rectory	Collection . . .	215·40
	„	31	Mr. H. A. Ward, Rochester .	Collection . . .	618·30
	June	10	Prof. van Rees, Amsterdam .	Various . . .	20·
	„	13	Science and Art Museum, Dublin	Various . . .	120·75
	„	17	Univ. College, Aberystwith .	Various . . .	13·50
	„	18	Christian College, Madras .	Collection . . .	174·
	„	20	Zoolog. Inst., Munich . .	Amphioxus . . .	10·50
	„	29	Zoolog. Inst., Heidelberg . .	Brachiopods . .	11·25
					17449·95

Report of the Committee, consisting of Professor NEWTON, Mr. JOHN CORDEAUX (*Secretary*), Mr. J. A. HARVIE-BROWN, Mr. R. M. BARRINGTON, Mr. W. EAGLE CLARKE, *and the* Rev. E. P. KNUBLEY, *appointed to make a digest of the observations on Migration of Birds at Lighthouses and Lightvessels which have been carried on from* 1879 *to* 1887 *inclusive by the Migrations Committee of the British Association (with the consent of the Master and Elder Brethren of the Trinity House and the Commissioners of Northern and Irish Lights), and to report upon the same.*

SINCE the last meeting of the Association the Committee have to report that Mr. W. Eagle Clarke, of the Museum of Science and Art at Edinburgh, who undertook to prepare a digest of the observations in connection with the investigation which was carried out from 1879 to 1887, has made very considerable progress with the systematic tabulation of the facts on a method that permits of realising the importance or otherwise of each separate movement. Taking into consideration, however, the enormous bulk of material to be consulted, and the somewhat limited hours for private work at Mr. Clarke's disposal, some time must yet elapse before it is possible to complete the work in a sufficiently concise and satisfactory manner, so as to justify the Committee placing the results before the Association. They would, therefore, respectfully solicit their reappointment as before.

Third Report of the Committee, consisting of Mr. A. W. WILLS (*Chairman*), Mr. E. W. BADGER, Mr. G. CLARIDGE DRUCE, *and* Professor HILLHOUSE, *for the purpose of collecting information as to the Disappearance of Native Plants from their Local Habitats. Drawn up by* Professor HILLHOUSE, *Secretary.*

IN compiling the present Report the Committee has confined its attention mainly to the north of England and the Isle of Man, adding, however, a few memoranda having reference to South Wales, these latter being interesting in view of the visit of the Association to Cardiff in 1891. In preparing the following list the Committee has been guided by the same rules as in former reports, only deviating from them for the purpose of including some case likely to be of special interest to botanists, such as Nos. 23, 54, 1,026, 1,063, 1,091, 1,169, and 1,652. The numbering and nomenclature are those of the 'London Catalogue,' ed. 8, corrected reprint of 1890.

In the collection of the Yorkshire records the Committee has to express its great indebtedness to the active assistance of an influential local committee formed by the Yorkshire Naturalists' Union, Mr. Charles P. Hobkirk being chairman. This local committee apparently experienced a like difficulty to ourselves in inducing local botanists to take the needful trouble in order to send in reports. Less than 10 per cent. of our own circulars elicit a reply, and the Committee therefore feels bound to commend to the notice of the secretaries of local societies the example of one such, who, having sent on the circular to the botanical recorder of his society, and being informed that the latter wouldn't 'bother' to answer the questions, considered that it was 'only fair' to his society to make a report, and therefore compiled one for himself.

As in the last Report, the partial or complete extirpation of ferns forms a considerable proportion of the lists of the Committee's correspondents, the tourist in part, but in greater degree the 'collecting dealer,' being held responsible. The Committee particularly regrets also to have to draw attention to the rapidly approaching extermination of *Cypripedium Calceolus*, and hopes that strenuous efforts will be made to protect it in its few remaining stations.

It is grievous to every lover of plants to read the accounts received from all quarters of the ruthless stripping of every accessible station of its floral treasures. While it is hardly practicable, or even desirable, to seriously interfere with the wish of the tourist to *gather for himself* some living memento of a pleasurable visit (however much it may be felt that there are better ways of obtaining possession of the plants than this), the various correspondents are practically unanimous in expressing a wish that in some way the law of trespass or of wilful damage should be brought to bear upon the collecting dealer, without the systematic ravages of whom they believe that any approach to extermination would in most cases be impossible.

3. *Thalictrum minus*, L. S. Wales; formerly abundant at Giltar, near Tenby, now almost extinct (F. W.).

[23. *Ranunculus sceleratus*, L. S. Wales; a case of extending distribution, a large crop having sprung up in a marsh near Tenby within the last four years (F. W.).]

39. *Trollius europæus*, L. Yorkshire; gradually becoming much rarer round Richmond (E. B. W.).

40. *Helleborus viridis*, L. Cumberland; has been recently exterminated from its old quarters at Threapland Ghyll, near Aspatria, by the working of limestone quarries for the supply of stone to the iron furnaces at Maryport (W. H.).

54. *Papaver Rhœas*, L. Cumberland; not entirely extinct, but very greatly diminished in quantity within living memory from the gradual abandonment of cereal tillage all over the county, and especially in the upland districts. *P. dubium* and *P. Argemone* hold their ground much better (W. H.).

59. *Glaucium flavum*, Crantz. S. Wales; formerly plentiful on rocks and shore near Tenby, now almost extinct; depredations of visitors (F. W.).

127. *Brassica monensis*, Huds. I. of Man; disappeared from Douglas through improvements and building; from a like cause is in danger of extirpation at the Moiragh, Ramsay, where it was first found by Ray in 1670 (P. M. C. K.).

150. *Hutchinsia petræa*, R. Br. S. Wales; formerly plentiful on walls at Penally, near Tenby, now rare (F. W.).

152. *Crambe maritima*, L. Cumberland; formerly plentiful on coast between Maryport and Workington; has within living memory entirely disappeared, owing partly to tidal encroachments, but more to the establishment of ironworks and the accumulation of mounds of slag on its site (W. H.). Yorkshire; much scarcer on the sands at Coatham (R. B. S.).

161. *Helianthemum marifolium*, Mill. S. Wales; not uncommon a few years ago on edges of cliffs at Stack Rocks, Tenby, now very rare, probably through tourists (F. W.).

291. *Geranium sanguineum*, L. Yorkshire; scarcer on coast sandhills between Redcar and Marske (R. B. S.).

292. *Geranium striatum*, L. Cumberland; recorded in Watson's 'New Botanists' Guide,' p. 661, for between Flimby and Workington, in a clearly defined station, which is now built over (W. H.).

294. *Geranium phæum*, L. Yorkshire; now very rare round Richmond (E. B. W.).

316. *Rhamnus catharticus*, L. S. Wales; extinct at Flat Holm, Cardiff (J. S.). Almost its only station in S. Wales.

369. *Lotus angustissimus*, L. Cumberland; came up twenty-five years ago on a newly formed railway slope near Bullgill Station, on the Derwent Branch Railway, but year by year diminished in quantity, and has now disappeared (W. H.).

372. *Astragalus hypoglottis*, L. Yorkshire; formerly plentiful in Langton Wold, near Malton, but is now nearly extinct owing to the pasture being ploughed up; is still found in small quantity on some grassy banks near (M. B. S.).

416. *Rubus idæus*, L. Yorkshire; formerly plentiful in Dungeon Wood, near Huddersfield, but destroyed by railway embankment and cutting (C. P. H.).

544. *Saxifraga tridactylites*, L. S. Wales; diminishing in neighbourhood of Cardiff (J. S.).

561. *Cotyledon umbilicus*, L. S. Wales; diminishing in neighbourhood of Cardiff (J. S.).

611. *Eryngium maritimum*, L. Yorkshire; very rare, if not extinct, at Lazenby, Redcar (R. B. S.).

629. *Carum verticillatum*, Koch. S. Wales; formerly plentiful at Saundersfoot and Rhode Wood, near Tenby, now very scarce, probably from ravages of botanical collectors (F. W.).

651. *Œnanthe fistulosa*, L. Cumberland; until about 1874 grew on edge of Salta, or Saltholm Moss, near Allonby, where it has not lately been found (W. H.).

661. *Meum athamanticum*, Jacq. Cumberland; formerly at Fell End in Ennerdale; now reported to be extinct (W. H.).

684. *Sambucus Ebulus*, L. S. Wales; extinct at Cogan Pill, near Cardiff, from railway construction (J. S.).

733. *Erigeron acre*, L. Cumberland; formerly at Dalston, near Carlisle; apparently extinct through road-making (W. H.). This was apparently its only Cumberland station.

750. *Inula crithmoides*, L. S. Wales; formerly pretty common on the rocks at Lydstep, near Tenby, now only in inaccessible places, probably from visitors (F. W.).

779. *Doronicum Pardalianches*, L. Cumberland; formerly on embankment at Brayton Hall, probably brought with the material, but has gradually died out (W. H.).

823. *Cichorium Intybus*, L. S. Wales; formerly common round Tenby, now almost extinct, probably from visitors gathering the flowers (F. W.).

928. *Pyrola rotundifolia*, L. Yorkshire; formerly at Birch Cave, near Middleton-one-row, but now very rare, if not extinct (R. B. S.).

934. *Statice Limonium*, L. Yorkshire; formerly very abundant in marshes between Coatham and Middlesbrough, now scarce (R. B. S.).

944. *Primula farinosa*, L. Yorkshire; gradually much rarer round Richmond (E. B. W.). Formerly plentiful in a marshy field near Darlington Waterworks, now much scarcer, probably from botanists and others (R. B. S.). Formerly on stream-side, Gordale Scar, Upper Airedale, but now extinct, probably from collectors (C. P. H.).

966. *Blackstonia* (*Chlora*) *perfoliata*, Huds. S. Wales; almost extinct in many localities round Tenby, probably from visitors (F. W.).

979. *Menyanthes trifoliata*, L. Yorkshire; wet places, Littondale, 700 feet; extinct through drainage (W. S. S.).

990. *Lycopsis arvensis*, L. S. Wales; round Tenby, where it was always rare; it has apparently quite disappeared, no doubt from visitors gathering the flowers (F. W.).

1,020. *Hyoscyamus niger*, L. S. Wales; apparently extinct at Manorbier, near Tenby, probably through visitors gathering it (F. W.).

1,026. *Verbascum Blattaria*, L. Cumberland; 'mentioned by the Rev. Jno. Dodd, Vicar of Aspatria in 1800, as being common in the churchyard there, but unknown in 1850 and onwards, till in 1872, when the adjacent vicarage came to be rebuilt and the garden levelled, when the plant reappeared in hundreds' (W. H.).

1,063. *Veronica Chamædrys*, L. S. Wales; has considerably diminished in cultivated ground round Tenby from some unknown cause, and its place appears to be taken by *V. Buxbaumii*, Ten. (*V. persica*, Poir.)

1,091. *Lathræa Squamaria*, L. Reference is made (W. H.) to a habit this plant is said to possess of disappearing from a station for the time being and reappearing in exactly the same spot after an interval of thirty or forty years. Can instances of this be given?

1,169. *Plantago arenaria*, L. Cumberland; in 1884 grew abundantly (along with *Adonis autumnalis*) in a flax crop on a farm at Flimby, no doubt being introduced with the seeds; both have disappeared, but the plantain has since appeared upon ballast heaps near Workington (W. H.).

1,256. *Euphorbia Portlandica*, L. Cumberland; formerly grew on the Solway shore between Maryport and Workington, and especially on the beach at Flimby, but, like No. 152, has disappeared, and from the same causes. In 1888 a single plant was noticed close to Flimby railway station, but it disappeared after a high tide in 1889 (W. H.).

1,344. *Epipactis palustris*, Crantz. Yorkshire; once not uncommon at Hellkettles, near Darlington, but now almost extinct, being eradicated by botanists and collectors (R. B. S.). S. Wales; extinct at Culver House, near Cardiff, from formation of new Barry Railway (J. S.).

1,358. *Ophrys apifera*, Huds. S. Wales; has quite disappeared from the neighbourhood of Tenby through visitors, &c. (F. W.). Has been exterminated from some stations in the neighbourhood of Cardiff through indiscriminate gathering (J. S.). From one station the extirpation of this, together with four ferns (*Osmunda regalis*, *Adiantum Capillus-veneris*, *Polystichum angulare*, and *Asplenium marinum*), all referred to after, is attributed by our correspondent 'to a . . . . parson who came here and thought he was justified in selling them for the benefit of what he called his "mission station."'

1,361. *Ophrys muscifera*, Huds. Yorkshire; has disappeared from a wood in Littondale (W. S. S.). S. Wales; has quite disappeared from the neighbourhood of Tenby through visitors, &c. (F. W.).

1,369. *Cypripedium Calceolus*, L. Yorkshire; has disappeared from the woods on the south side of Littondale, through 'botanical robbers' (W. S. S.). Similar reports have been received as to its Durham stations, where it is described as 'nearly eradicated by collectors for trade purposes.'

1,390. *Asparagus officinalis*, L. S. Wales; extinct at Grangetown, Cardiff, through extension of ship-building yards (J. S.).

1,421. *Colchicum autumnale*, L. Cumberland; up to about 1864 was fairly abundant in a meadow near Blennerhassett, on the R. Ellen, but was then lost through draining and ploughing (W. H.). This was probably its most northern native station.

1,424. *Paris quadrifolia*, L. Yorkshire; has gradually become much rarer round Richmond (E. B. W.). Formerly in the woods near Storthes Hall, near Huddersfield, but apparently exterminated by 'the rapacity of collectors' (C. P. H.).

1,613. *Carex punctata*, Gaud. S. Wales; apparently extinct at Waterwynch, near Tenby (F. W.).

1,652. *Phleum arenarium*, L. Cumberland; formerly found, with 152, 1,256, &c., on the beach at Flimby, but finally disappeared after a storm early in 1884. From St. Bees Head northwards the sea has for many years past been gradually making inroads upon the land (W. H.).

1,764. *Adiantum Capillus-veneris*, L. I. of Man; is now very scarce, and in danger of extermination from its sale to 'trippers' in the Douglas Market; 'loafers' go in boats with ladders, and procure it from the rocks to sell it in the towns (P. M. K.). S. Wales; much rarer round Cardiff, though nowhere extinct. See No. 1,358 (J. S.).

1,766. *Cryptogramme crispa*, R. Br. I. of Man; is now very scarce, and in danger of extermination from its sale to 'trippers' in Douglas Market (P. M. K.).

1,771. *Asplenium marinum*, L. Cumberland and Westmoreland; is rapidly diminishing in the Lake district generally through the action of 'rapacious local dealers' and tourists (W. H.). S. Wales; is much rarer round Cardiff, but nowhere extinct. See No. 1,358 (J. S.).

1,772. *Asplenium viride*, Huds. Cumberland and Westmoreland; has entirely disappeared from a well-known station at Brandy Ghyll, a deep gully at the S.W. base of Carrock Fell, and is now quite scarce in many of its remaining recorded habitats in the Lake district, &c., through collectors and tourists (W. H.). Durham and Yorkshire; is much scarcer in all its Teesdale localities, Falcon Clints, and Green Fell, &c., through tourists and collectors (R. B. S.).

1,773. *Asplenium Trichomanes*, L. Cumberland and Westmoreland; rapidly diminishing in the Lake district generally through 'rapacious local dealers' and tourists (W. H.). Yorkshire; formerly in Dungeon Wood, near Huddersfield, in clefts of the rocks, but is now extinct, partly from collectors and finally through the construction of a railway (C. P. H.).

1,781. *Ceterach officinarum*, Desv. Cumberland; formerly grew on many of the southern bluffs of Gowbarrow Fells over Ulleswater, where hardly a single specimen now exists; Aira Crag, Yew Crag, and Priest Crag, formerly well-known stations, have been completely denuded; collectors and tourists are responsible (W. H.). I. of Man; the plant is scarce in the island; near Ramsay it is extinct, owing to removal of the old walls (P. M. K.).

1,782. *Scolopendrium vulgare*, Symons. Cumberland and Westmoreland; is rapidly diminishing in the Lake district generally through local dealers and tourists (W. H.). Yorkshire; formerly grew profusely in the neighbourhood of Richmond, but is now becoming scarce in consequence of the depredations of professional fern-collectors (E. B. W.). Formerly fairly plentiful at Hazlegrove, Saltburn, but now almost totally extinct through visitors, collectors, &c. In other glens in the neighbourhood it is also becoming rare from the same cause (R. B. S.). I. of Man; not very plentiful in the island; it is now fast disappearing from the glens, as *e.g.*, Ballure, owing to people, mostly the 'trippers,' carrying off roots. Other ferns, besides those specifically mentioned in this report, are being diminished from like causes, but not to such an extent (P. M. K.).

1,783. *Woodsia ilvensis*, R. Br. Durham and Yorkshire; formerly in several localities in Teesdale, &c., but now quite extinct through the action of collectors (R. B. S.). This was its most southern English station.

1,785. *Cystopteris fragilis*, Bernh. Cumberland, &c.; associated with No. 1,781, and has similarly suffered, but not to so great an extent (W. H.).

1,788. *Polystichum Lonchitis*, Roth. Cumberland, &c.; rapidly diminishing in the Lake district; 'rapacious local dealers and tourists' (W. H.). Durham and Yorkshire; formerly in several localities in Teesdale, but now quite extinct; collectors, &c. (R. B. S.). Rocks in the high pastures, Littondale; 'botanical robbers,' and possibly also severe weather (W. S. S.).

1,790. *Polystichum angulare*, Presl. S. Wales; round Cardiff is much rarer, but nowhere extinct. See No. 1,358 (J. S.).

1,798. *Lastræa spinulosa*, Presl. S. Wales; almost extinct in Rhode Wood, near Tenby, no doubt from fern-hunters and visitors (F. W.).

1,800. *Lastræa æmula*, Brackenbridge. S. Wales; as with No. 1,798. Some ten or twelve years ago a cartload of plants might have been got (F. W.).

1,806. *Osmunda regalis*, L. Cumberland; formerly quite abundant round Derwentwater and Borrowdale, but now extinct. At one time the plant, known locally as the 'bog-onion,' was so plentiful round Gosforth, &c., that the farmers used the dried fronds as a covering for their potato-carts, to protect the contents from frost when attending the markets at Whitehaven or Egremont (W. H.). Yorkshire; formerly in Marsh Wood, near Huddersfield, but extirpated by building (C. P. H.). I. of Man; is still plentiful, but now for some years has been taken to Douglas by the cartload and sent off by steamer (P. M. K.). S. Wales; getting gradually rarer round Cardiff, but nowhere extinct. See No. 1,358 (J. S.). Has now almost disappeared from the neighbourhood of Tenby, where it formerly grew in the wet fields everywhere; carried away by visitors (F. W.).

1,807. *Ophioglossum vulgatum*, L. Yorkshire; formerly grew on the banks on the south side of Littondale, but has not been seen for the last five or six years (W. S. S.). Our correspondent wishes to know whether it is the habit of this plant to disappear for a time, as he feels sure it has not been removed.

Fourth Report of the Committee, consisting of Professor FOSTER, Professor BAYLEY BALFOUR, Mr. THISELTON-DYER, Dr. TRIMEN, Professor MARSHALL WARD, Mr. CARRUTHERS, Professor HARTOG, *and* Professor BOWER (*Secretary*), *appointed for the purpose of taking steps for the establishment of a Botanical Station at Peradeniya, Ceylon.*

THE Committee report that during the year a proper water supply has been led into the laboratory in the Royal Gardens, Peradeniya, and a sink has been provided. The expense entailed has been larger than was at first anticipated, owing to the fact that the water could not be drawn directly from the river close at hand, but had to be brought by pipes a distance of about 450 yards. The total cost has been over 50*l.* The Committee have devoted 25*l.* towards meeting this cost, and the balance of the expense has been undertaken by the Ceylon Government. No further expenses have been incurred during the year, owing to the fact that the laboratory has not been occupied; but, considering the large personal expenses which must be incurred by any one using the station, the Committee do not anticipate that a succession of applications will ever be regularly maintained. An application for use of the station during the coming year is, however, in the hands of the Committee. In order to meet the further expenses of equipment of the laboratory to suit the convenience of students, and to make it permanently useful, and in consideration of the fact that the Committee have been able to return half of the money granted last year, they request that they may be reappointed, and that the sum of 50*l.* be placed at their disposal.

Report of the Committee, consisting of Professor HADDON, Mr. W. E. HOYLE (*Secretary*), *and* Professor W. A. HERDMAN, *appointed for improving and experimenting with a Deep-sea Tow-net, for opening and closing under water.*

THE report which this Committee had the honour of presenting at the last meeting of the Association concluded with the statement that an attempt was being made so to modify the net that it should be opened and closed, not by the agency of sliding weights, but by an electric current. The work of the past twelve months has been a successful endeavour to carry out this programme.

The new apparatus, of which hitherto only a provisional model has been made, is in its main principles very similar to the one already described. No change of importance has been made in the net itself, but the Committee has procured a net-frame, made according to the design advocated by Professor Hensen, of Kiel, which contains some improvements in points of detail, and appears likely to render very efficient service.

The mode of opening and closing the net by the successive detachment of two cords, or links, has been retained; but these are now looped round the shorter arms of two bell-crank levers, the longer extremities of which rest upon two studs projecting laterally from the sector of an escapement wheel near its circumference. The lengths of the levers are so adjusted that when the first tooth of the escapement is liberated one of them falls, whilst the second is retained until the third tooth has been liberated.

The escapement sector is actuated by a spring, and its movements are controlled by an electro-magnet, whose armature is attached to, or rather made solid with, the escapement itself.

The current passes to the magnet down a wire in the rope by which the net is towed, and when the net is let down closed the circuit is open.

As soon as the desired depth has been reached contact is made, the movement of the armature releases the first tooth of the escapement, and the net opens. When the circuit is broken the second tooth of the sector is caught by the escapement, and held until a second contact sets free the other lever and closes the net.

The apparatus has been tried, first, in a fresh-water pond in the vicinity of Manchester, and secondly, on one of the dredging excursions of the Liverpool Marine Biology Committee in the s.s. *Hyæna*. The facilities for experiment on this occasion were extremely great, as the vessel was provided with a dynamo, and the apparatus worked successfully to a depth of from ten to fifteen fathoms.

The funds at the disposal of the Committee were not sufficient to enable them to hire a vessel for making further trials in deep water, and their efforts to obtain an opportunity of doing so by any other means have failed; but it is hoped that the means may be forthcoming during the next twelve months.

The thanks of the Committee are due to Messrs. B. and S. Massey, who have constructed the new lock gratuitously, and thus enabled the work of the Committee to be done much more economically than would otherwise have been possible; to the Liverpool Marine Biology Committee for the possibility of utilising the cruise of the *Hyæna* for the trials; to Mr. J. A. Henderson for the loan of one of his very conveniently

arranged bichromate batteries, which was of great use in the experiments; as well as to Professor Schuster, F.R.S., and Mr. Haldane Gee for assistance and advice.

The probable Effects on Wages of a general Reduction in the Hours of Labour. By Professor J. E. C. MUNRO, *LL.D.*

[Ordered by the General Committee to be printed *in extenso.*]

SECTION I. *Introduction.*

A 'GENERAL REDUCTION' in the hours of labour implies, strictly speaking, a reduction of working hours in all trades. It would be interesting to discuss the effects of such a reduction, assuming that the amount of the reduction in each trade was proportionate to the hours worked previous to the change. But no one has made such a proposal, and in order to avoid the charge of introducing before this Section a practical question of the day in too academic a form, I propose to assume that a general reduction of the hours of labour means a reduction of hours in those industries in which the hours of labour greatly exceed what may be called 'a normal day.' By a 'normal day' is not to be understood a day of a fixed number of hours—*e.g.*, an eight-hours day. A fixed, unvarying day for every worker is impossible because (apart from the varying degrees of intensity of labour in different industries) of the necessity for preliminary work before the bulk of the labourers can begin their daily toil. The miner, for instance, cannot go down the mine until the engineman has started the necessary machinery. Hence the more rational proposals to establish a short working day recognise that some latitude ought to be given in particular industries. In textile factories the present working hours are 56½ per week. We may assume, however, for the purposes of this paper, that a 'normal week' for all skilled industries, due allowance being made for preliminary work, would correspond to 48 hours. From this point of view industries may be divided into three classes:—

1. Those in which a normal day has already been established. In Cornwall, for instance, an eight-hours day has been in force for a long period of time in the mining industry.

2. Those in which the reduction would be of a moderate amount. Under this class may be placed industries where the reduction would not exceed 8½ hours per week—*e.g.*, if the working week was reduced from 56½ to 48 hours.

3. Those in which the reduction would be very substantial in amount.

The abolition of overtime would merely reduce still further the hours of labour in those industries where it is practised; and in order to avoid any difficulties as to overtime it will be assumed that all overtime is reduced in the same proportion as the hours of labour.

'Wages' I take as meaning 'real' wages as opposed to money or nominal wages.

The method of obtaining the reduction in hours does not come within the scope of this paper. It will be assumed that whether a general reduction in the hours of labour be brought about by agreement or by the State is immaterial as regards economic effects, though it is of the highest importance as regards economic friction, and as regards fixing the moment of time when the reduction is to take place.

It is proposed to discuss the main subject from three points of view, viz., produce, capital, and international trade.

SECTION II. *Effects as regards Produce.*

A general reduction in the hours of labour will at first reduce the net produce [1] available for distribution amongst producers. It is true that (*a*) any improvement in the efficiency of labour due to shorter hours,[2] (*b*) the impulse that may be given to the invention of labour-saving appliances,[3] or (*c*) greater economy in the use of labour, will tend to lessen the reduction in produce; but in all industries of the second class (*i.e.*, where the reduction is moderate in amount), a class that includes most of the skilled industries of the country, the reduction in produce will at first correspond very closely to the reduction in hours. A cotton-spinner spins practically as much during the last hour as during the first hour of the day, and in the opinion of competent judges a reduction of one-eighth in the hours of labour in the cotton trade would practically reduce the produce one-eighth also. Improved machinery might in time obviate this, as it did after the Factory Acts were passed; but there are many industries in which improvements in production operate but slowly;[4] and it must be remembered that the conditions, especially as regards foreign competition, under which production is now carried on have greatly altered since the introduction of factory legislation.

The produce may be reduced in some trades in a greater proportion than the reduction in the hours of labour by the effects at the margin of cultivation. A farm, or even a factory, possessing so few advantages, as regards either fertility or situation, that it yields barely sufficient to pay ordinary interest and wages, may cease to be profitable, and may go out of cultivation, or cease to be worked. In such a case the reduction in hours not only reduces the net produce, but throws capital and labour out of employment.

It has been suggested that the net production could and would be maintained (if not increased) by the employment of the unemployed. Such a suggestion implies that there is a class of unemployed possessing the requisite physical powers, mental intelligence, and technical skill required in the industries where the hours of labour are reduced. No such assumption can be granted. Indeed, there is ample ground for contending that, as far as skilled industries are concerned, the bulk of the unemployed do not possess the necessary skill to engage in them. It must not be forgotten that division of labour has been carried out to such an extent in this country that a skilled artisan may be totally unfit for any industry except that for which he has been trained; hence there may be skilled artisans out of employment and trades seeking skilled artisans at one and the same time. Even in what are called unskilled industries physical strength is usually a necessity, and amongst the chronic unemployed it is, as a rule, wanting. The length of the hours of labour is not the chief cause of want of employment. Excessive hours of labour are themselves the result of causes which would largely remain in force even if the hours of labour were shortened,[5] and whilst the

[1] By 'net produce' is meant the total amount of new wealth produced in a given time, *e.g.*, in a year.

[2] *Report on Depression of Trade*, Q. 11,935.

[3] See Appendix (*a*).

[4] 'The reduction of hours in the flax-spinning trade reduced the output in proportion, no relief being obtained from improved machinery.'—*Report on Depression of Trade*, Q. 7,012.

[5] See Miss Potter's article on the 'Sweating Committee' in *Contemporary Review*, June 1890.

shortening of hours might benefit in one way the unfortunate class whose condition is described in the 'Lords' Report on Sweating,' it will not of necessity maintain or improve their wages. 'We give out our work to whoever will take it, to the man who will do it best and the cheapest, and we get off with the least trouble,' says the employer. 'We cannot check the supply of native workers,' says Miss Potter. . . .[1] 'The large supply of cheap female labour, occasioned by the fact that married women, working at unskilled labour in their homes . . . and not wholly supporting themselves, go forth to work at what would be starvation wages to an unmarried woman.' Shorter hours of labour may coexist with poverty, especially where the supply of unskilled labour is large and combination is absent. Low wages are largely responsible for the long hours of the unskilled worker, and the first step towards the amelioration of his position would be a rise in wages rather than a shortening of hours, as the latter would follow the former.

It must also be remembered that unless a man is a 'wealth-creating' worker the community will derive no benefit from his labour. It is possible for a man to work, and yet to destroy more than he produces; in such a case the community may find itself benefited by supporting that man in idleness rather than by allowing him to destroy, under the guise of producing, wealth. The State is not, therefore, of necessity a gainer by the employment of the unemployed—it only gains in so far as such employment results in a real increase of wealth.[2]

On the other hand, it has been suggested to me by a keen observer that to give employment even to a wealth-destroyer might be regarded as an alternative plan to our present system of poor relief. The objection to such a method of supporting unproductive individuals in this way lies in the fact that the burden would fall on particular employers instead of being borne by the community as a whole or by some definite section thereof.

Let us, however, assume that by the employment of additional hands the net produce (say in a year) is maintained. We have now the same amount of net produce as before, but a greater number of producers. In other words, though the total produce is the same the production per producer per year is reduced, and from the point of view of distribution the net production per head per annum is of greater importance than the net produce.

The argument that the production might be increased by the system of 'shifts' was met by the statement of one of the witnesses examined before the Royal Commission on the Depression of Trade. 'If you produced double the quantity of goods, and there was no demand for them . . . you would be compelled to sell the goods at a cheaper rate, and instead of benefiting the manufacturer and the workman, it would injure them: they would have such a large stock of goods that they would come to a deadlock.'[3] Resort might be had to 'shifts' in order to maintain the net produce, but this would only be possible in those industries

[1] *Contemporary Review*, ante.

[2] It is on this principle that Mr. Booth's suggestion of a State-supported class is based. The same principle applies to employers. See Appendix (*b*).

[3] Q. 1,334.

where a double shift, working the reduced hours, would produce the same quantity as a single shift working the original hours.[1]

Before considering on which of the classes of producers loss in production will fall the question arises, Will the loss be restricted to those industries (A) in which the reduction takes place, or will it extend to other industries (B)? If the A producers consume their own products the loss will fall on them; but, as a rule, one form of wealth is created in order to be exchanged for another form, and hence to the extent that the B producers are consumers of the A produce they will participate in the reduction of the net produce. If the demand of the B producers continues in intensity they may have to bear the whole loss: on the other hand, the demand may fall off to such a degree that the A producers will suffer; but the probability is that the loss will be shared between the two classes, and therefore all industries will tend to be affected.

The reduction in hours being supposed to be unequal in the different trades that form the A group, the corresponding reduction in net produce will also be unequal. Hence producers and consumers will be unequally affected, and the 'economic equilibrium' that existed previous to the reduction in hours will be disturbed. Capital and labour will then tend to migrate from one industry to another until a new equilibrium is established, under which each industry will, everything considered, hold out a hope of the same reward to the producer.

Add to this, that the proposal for a working day of a fixed number of hours takes no regard of many elements that enter into the determination of the amount of net produce that an industry must yield in order to attract capital and labour. For instance, the 'intensity' of labour is one of the important factors in determining the reward of labour. A fixed, unvarying working day would apparently require from the man whose labour is heavy and trying the same number of hours' work as from him whose labour is light and easy. But working men—so long as human nature is what it is—will expect that the degree of irksomeness in their work will, if ignored in the hours of labour, be recognised in the reward of labour. By the migration of labour this result will be attained.

The migration of capital or of labour will depend on several circumstances. Fixed or sunk capital cannot easily be moved from one industry to another. A railway is immovable, and any loss resulting from a reduction of hours cannot be avoided except by a sacrifice of the capital represented by the permanent way. The shaft of a mine, too, cannot be removed, but the profits of mining are supposed to replace the capital spent in sinking the shaft before the lease of the mine expires. Machinery wears out in a given time, but by allowing for depreciation capital spent on building returns to the capitalist. The argument that fixed capital is immovable cannot, therefore, be taken but with large limitations arising out of the 'degree of fixity.' Besides, fixed capital is not co-extensive with wealth devoted to production. Various economists have pointed out the influence on production of 'loan capital.' The great characteristic of such capital is that it exists in such a form that it can readily be diverted from one industry to another; and we may expect that it will seek those industries in which there is the possibility of the greatest reward.

[1] The extent to which shifts may be adopted is discussed under the section devoted to capital.

Just as there are checks to the migration of capital so there are hindrances to the migration of labour. These have been dwelt upon by all economic writers, and they need not be enumerated. Admitting their existence, as well as the barriers in the way of migration of capital, there will, nevertheless, be a tendency towards migration where any disturbance of economic equilibrium occurs, and in this way the effects of a reduction in the hours of labour in some of the industries of the country may possibly be far-reaching and affect industries generally.

Assuming, as we are justified in doing, that the net produce per producer per annum will tend to be reduced by a reduction in the hours of labour—the number of producers remaining the same, but the net produce being diminished, or the net produce remaining the same, the number of producers being increased—it remains to consider on which of the producing classes—landlords, capitalists, and labourers—the loss will tend to fall.

Theoretically it might be argued that the loss will tend in the first instance to fall on the landlord, inasmuch as the art of production will tend to be increased, and land at the margin of cultivation will tend to go out of cultivation. The surplus available for rent will be decreased. We ought not, however, to ignore the fact that at the margin of cultivation there is no rent on which the loss can fall. A certain amount of land may, as we have seen,[1] go out of use or of cultivation, and the capital and the labour employed on such land will compete with the capital and the labour engaged in other industries, thus sending down both profit and wages. Further, to the extent that land goes out of use or of cultivation, the supplies of either the raw material of industry or of food will be decreased. If industry be checked by the want of raw material, interest and wages will be further decreased, whilst a diminished supply of food will tend to lessen still further real interest and real wages. But it may be said that industry will require the same amount of raw material as before, and labour will demand the same supply of food. This is possible; but the former cultivators on the margin will only resume their occupations when others are willing to give them in exchange for raw material or food such an extra amount of produce as will cover the loss sustained by the decrease in the hours of labour. This extra produce must come out of the amount available for interest and wages in other industries; and thus a loss, which in the first instance fell on the landlord, might ultimately tend to be thrown, in part at least, on the capitalist or on the labourer or on both.

I have assumed that the only industries on the margin are those producing food or raw material. What would be the result if we suppose that every industry in which the reduction takes place has a 'margin of cultivation' at which point no rent is payable? For the sake of simplicity, let it be assumed that the consequent reduction in the amount of raw material and of food corresponds to the reduction in the product of manufacturing industry. Produce rents will fall, and the capital and labour set free will either remain idle or go to reduce interest and wages in all industries. In other words, the loss in the first instance tends to fall on the landlord, but a portion of such loss will be eventually transferred to interest and to wages.

[1] *Ante*, p. 473.

In manufacturing and in mining industries rent may often be eliminated—as, for instance, where the land on which a factory is built belongs to the capitalist as part of his capital, or where a mine is leased for a definite time at a fixed rent. The question of the effects of a reduction of hours may in such cases come to be one between the capitalist (assuming him to be also the employer) and the labourers. Which will suffer?

We have seen that a reduction of hours in some trades will tend to affect all other trades, inasmuch as by the migration of capital and labour the reduction in the net produce may be spread over all industries. Whether the capitalist or the labourer will bear the loss will depend largely on two considerations, viz. (1) the extent to which labour or capital migrates to foreign countries, and (2) the effects of the reduction of hours on population and on capital. The effects on capital are so important as to require separate consideration; and since population will not be directly affected we have only to consider the possibility of capital and labour migrating to other countries. In this respect capital has the advantage. Owing to the growth of banking and financial houses, and the development of foreign trade, capital possesses an international organisation, and can be promptly and readily directed to the best openings. Labour, on the other hand, moves slowly; it deteriorates by non-use, and possesses no international organisation. It is therefore highly probable that a large share of the reduction in the net produce, due to shorter hours, will be thrown upon labour.

It remains to consider how far the foregoing conclusions may be affected by (1) monopolies; (2) combination; (3) methods of paying wages.

(1) A monopolist, whether a private person, or a group of persons, or a municipality, or a state, will in some cases be able according to the intensity of the monopoly to throw the whole or part of the loss due to a reduction in the hours of labour in his industry upon those who use the article or the service subject to the monopoly. For example, a corporation that has the sole right of manufacturing and vending gas may by raising the price of gas reduce the hours of labour without affecting profits or wages. The power of raising the price will be limited by the advantages possessed by other luminants. The loss is thrown upon the community, including labourers if they use gas. The Post Office might reduce the hours of labour at the expense of the senders of telegrams, though not so easily at the expense of the senders of letters, owing to the fact that small variations in postage are not always practicable.[1]

Even where the monopoly does not arise from law, but is due to limited resources being owned by one or by a few persons, any loss due to a reduction in the hours of labour will tend to fall on the consumer if the produce is of such a nature that the community, rather than be without it, will give an increased value for it. There might, however, be a rise in the values of monopolised articles without affecting real wages. The labourers usually confine their consumption to certain groups of articles; and in considering how they are affected as consumers, regard must always be had to the articles that form the chief part of their consumption.[2]

[1] But small variations could be introduced in the price of post-cards.

[2] For a detailed discussion of the causes that affect the price of different types of monopolies, see Marshall's *Principles of Economics*, p. 457.

(2) Combination may be resorted to by labour as a method of preventing outside labour from coming into an industry. For instance, the number of labourers may be restricted by rules regarding apprentices. The Trade Union rule that Unionists will not work with non-Unionists has sometimes a similar effect; though this difficulty may be avoided by providing different workrooms for the two classes of workers. To the extent that combination enables producers to control the production of a given article to that extent, a trade may escape sharing in a loss due to a reduction of hours in other trades. Combination amongst capitalists falls under the head of monopolies, but there might be an agreement amongst employers not to employ men holding particular religious or political views or men belonging to trade unions.

(3) Hitherto the methods of paying wages have not been taken into account. As a rule wages in the skilled trades are paid by piecework; the spinner and the weaver receive a certain rate of wages for every yard they spin or weave respectively; the miner is paid by the ton, and the bricklayer by the yard. In other trades wages are paid by the hour, whilst in the unskilled industries wages are paid by the day of a varying number of hours. A reduction of hours where piecework prevails would not *ipso facto* affect the 'rate' of wages, but would lessen the 'amount' of wages, inasmuch as a fewer number of yards would be woven and a fewer number of tons obtained in the shorter hours. The wages earned in a year would be reduced in proportion to the reduction in hours. But this would not leave the capitalist in the same position as before, as he would have a smaller gross return on the same amount of fixed capital; and if he has only been receiving an economic return before, a reduction in the 'rate' of wages may be required to prevent a migration of capital into some other industry.

Where wages are paid by the hour similar results would follow.

In both the above cases the method of paying wages is such that a reduction of hours reduces automatically the 'amount' of wages without affecting the 'rate' of wages; but where labour is paid by the day the method of payment will, if no alteration takes place, continue the same wages as before for a smaller amount of labour. If the economic equilibrium is to be maintained the 'rate' which in these cases is the same as the 'amount' of wages will have to be reduced; and it may be admitted that a reduction in the rate of wages is always a matter of difficulty. It is therefore quite possible that whilst in piecework wages would at once fall in proportion to the reduction in the hours of labour, in day work the reduction might be for a time delayed.

To argue as some do that day wages govern piece wages is to assume a relation of cause and effect that does not exist. There is more reason for saying that piece wages govern day wages than that day wages govern piece wages, since piecework is the rule in all the chief industries of the country, and the skilled industries have greater effect on wages than the unskilled industries. The high piecework wages of the manufacturing county of Lancashire have raised the day wages of agricultural labourers and of domestic servants in the North of England. If day wages governed piece wages we would expect the wages in skilled industries to approximate to the low wages of farm labourers, but this has not been the case.

SECTION III. *As regards Capital.*

(1) In so far as the net produce is diminished a check will be given to the accumulation of capital. It is true that the motives or causes that lead to saving rather than to spending are very various, and that the addition to capital made in any one year is but a small portion of the total stock of the nation; nevertheless the amount of new wealth produced in a year is a material factor in determining how much can be saved in such year.

(2) Capital will tend to avoid undertakings where the reduction of hours lengthens the time of completion. A railway or a canal yields no return until constructed, and hence the length of time occupied by construction is a very material circumstance in determining whether the capital will be advanced or not.

Where interest is paid on capital out of capital during the construction of the works any extension of time will necessitate a corresponding increase in the capital required, just as any contraction of such time will reduce the capital required.[1]

Hence we reach the conclusion that the reduction in the hours of labour may check the accumulation of capital and cause at the same time an increased demand for it, and so raise the rate of interest. A rise in the rate of interest does not of necessity imply a reduction in wages; but where it is preceded by and is due to a reduction in the annual net produce in the state, it implies a fall in the shares taken by producers other than capitalists, and in manufacturing industry, apart from capitalists, labourers form the great bulk of the producers.

This line of argument must not be pressed too far, as a decrease in the supply of capital may be counteracted by an increase in its efficiency. On the Manchester Ship Canal the work proceeds by night as well as by day, and that without any increase in the requisite machinery. In mines it is immaterial, as far as the work is concerned, at what hour the miner descends; and the system of double shifts has been long known in Cornwall, whilst in Durham and Northumberland treble shifts are usually adopted. But there are very important limits to the extent to which the efficiency of capital can be improved in this way:—

(1) Fixed capital, such as machinery, is not a necessity in all trades.

(2) In some trades the requisite conditions do not exist. For instance, an industry may require different classes of labour, and a supply of one of these classes may not be forthcoming for night work as well as for day work. It is a noteworthy fact that whilst the Northumberland and Durham adult miners work a treble shift of less than eight hours, the boys in the mines work two shifts of over ten hours each.[2]

(3) The adoption of a double shift, say of eight hours each, instead of one shift of say ten hours or twelve hours, will increase production more than the reduction of hours diminished production, and as such a

[1] The shareholders in the Manchester Ship Canal Company receive interest during the construction of the canal, hence the engineer has orders to make the canal within the shortest time possible.

[2] It is difficult to see how to defend a method of working which imposes longer hours in a mine upon boys than upon grown-up men.

system is only possible in certain trades, its sudden adoption will affect relative values.

In so far as the producers in the trades where production is increased belong to 'non-competing groups' the benefit of increased production may go entirely to those engaged in industries where no increase in production is possible or takes place, and it is even possible that the variation in relative values may leave the first-mentioned producers worse off than before.

An illustration may be given. Suppose there are in a factory 100 men working 12 hours a day: the number of hours' work each day is 1,200. Suppose the hours of labour reduced to 8, then the 100 men will in one day work 800 hours. In order to maintain the aggregate produce 50 additional men will be required, working 8 hours a day; hence the second shift will have to consist of 50 men only. If 100 men instead of 50 were employed, the total production per day would be 1,600 hours, and it is possible, under the circumstances above mentioned, that the product of the 1,600 hours may exchange for the same amount of other commodities as the product of the original 1,200 hours. In such a case the consumers are benefited, but the 200 producers have, after the exchange, the same amount of commodities to divide as the 100 original producers.

Subject to these limitations there is no doubt that the efficiency of fixed capital in many industries might be largely increased, and such increased efficiency would tend to modify any loss that might fall on the labourer, owing to any decrease in the rate at which capital accumulates under a régime of shorter hours of labour.

SECTION IV. *As regards International Trade.*

Notwithstanding the enormous extent of the export and import trade between nations, there are numerous classes of commodities and services that each State must obtain within its own borders. Amongst such commodities and services may be mentioned :—

(*a*) Products that from their nature cannot be easily imported into an island like Great Britain—*e.g.*, water, gas, electricity—though their production is liable to be affected by the possibility of importing substitutes.

(*b*) Products that take the form of improvements to or erections on land, *e.g.*, railways, canals, roads, houses, and buildings.

(*c*) Services relating to the carriage of products from the producer to the consumer within the State.

(*d*) Services of those employed by the State, either directly or indirectly through local bodies.

(*e*) Domestic services.

(*f*) Services relating to the transport of individuals.

Other examples might be added, but these are sufficient to show that there are a large number of persons employed in producing forms of wealth, and in rendering services that do not enter into international trade. Would a reduction of the hours of labour in such employments affect the export and import trade of the country? No very definite answer can be given, but it is conceivable that capital and labour might be drawn off from other industries in order to maintain the aggregate of such products and services, and then the home demand for foreign commodities might decrease in intensity. Even if the aggregate be not maintained we reach the same conclusion, as the worker will have a decreased command over commodities, including imports and the 'reciprocal demand,' for the articles exchanged between nations will thus be affected.

Turning to the products of labour that are bartered between nations, a reduction in the hours of labour may (1) destroy the gain arising from international trade, or (2) only diminish it.

In discussing these two points, it is desirable to take two countries exchanging two products, and assuming the theory of international trade laid down by Ricardo, and explained and developed by Mill, Cairnes, Bastable, and other writers, to inquire how far, if at all, the net produce of the nation will be diminished by the effects of a reduction in hours on international trade. To the extent of any such diminution the results on wages, as regards the home trade already referred to, will be intensified.

Mr. Bastable ('Theory of International Trade,' p. 23) illustrates the gain from international trade as follows:—'Let it be granted that a unit of productive power in A can produce 10 x or 20 y, and that a unit of productive power in B can produce 10 x or 15 y. It follows from the law of comparative cost that it will be to the interest of A to confine itself to the production of y, and of B to devote its resources to the production of x.'

(1) The 'total gain' per unit of productive power, *i.e.*, the gain to be divided between A and B, is represented by 5 y. Assume a reduction in the hours of labour in A, in the y industries only, this reduction may be so great that a unit of productive power will now produce in A 10 x or 15 y—in other words, B has no longer any incentive to exchange x for y, inasmuch as it can produce y as well as x, under as favourable circumstances as A. The foreign trade in these two classes of commodities will cease, and A will find its net produce diminished.

(2) The reduction in hours may, however, only diminish the 'total gain,' *e.g.*: If A with a unit of productive power produces 18 y instead of 20 y, the total gain is reduced from 5 y to 3 y. Will this reduction fall on A or on B, or on both? The answer depends on the effect the reduction in productive power in A will have on the intensity of the 'reciprocal demand,' and though we may mention some of the conditions that will mainly affect the 'reciprocal demand' it is not possible to forecast with accuracy the amount of loss that will fall on A.

(i.) The demand for x may continue to be so intense in A, and the demand for y may so decrease in B, that the whole loss may be thrown upon A.

(ii.) On the other hand, the foreign demand may continue its intensity, whilst the home demand remains as before; in such a case the loss will tend to fall on the foreign country: the home country may even be a gainer.

(iii.) A third type of case may be mentioned, viz., that in which there is such a variation in reciprocal demand that the loss is divided between the two countries.

Where an exporting country possesses a monopoly of production arising out of climate or natural resources, it will be able to make a better bargain in the export market than if such a monopoly did not exist. To the extent that a country reducing its hours of labour possesses a monopoly of production it may throw a large portion of the loss on its foreign customers.

But a monopoly that depends on special productive power may be destroyed by a reduction in hours, and foreign customers may be able to obtain better terms from other States.

The relative importance to the two States of the article each imports is also very material as regards demand. The necessaries of life are more important to a nation than luxuries, and a decrease in supply in the former would probably not affect demand so much as a decrease of supply in the latter.

The possibility of finding a substitute amongst the commodities produced by trades where no reduction has occurred, may result in a new direction being given to foreign trade, with a consequent disturbance to industry.

These and other circumstances will tend to determine how much of the decrease in 'total-gain' will fall on the country that reduces its hours of labour.

If, instead of confining our attention to one or two articles, we look at foreign trade as a whole, the question becomes more complex, though the results of a reduction in hours will be governed by the considerations applied to the simpler case of two commodities.

A reduction in the hours of labour that is not universal, and yet is unequal in amount, will, apart from diminishing the gain arising from foreign trade, greatly disturb relative values, and tend, for a time at least, to disorganise industry. We cannot assume that the foreign demand for commodities will vary in each industry with the corresponding reduction in hours and in produce, or that such reduction will not affect the home demand for foreign produce. Even were we to suppose that we should lose none of our foreign trade, yet the direction of such trade would tend to alter, and the process of adjusting our industries to meet the changed conditions would undoubtedly tend to injure, at least for a time, the working classes.

If, however, the reduction in hours is general and uniform and applies to all industries, relative values will remain undisturbed, but if the output in every industry is diminished a smaller amount of exports will be available for exchange with foreign countries, whilst the 'total gain' may be diminished. As far as the home country is concerned, it has, owing to relative values being unchanged, the same incentive as before to export some commodities and import others, but whether foreign countries will or will not be prepared to give the same amount of their exports for a smaller quantity of the home country's produce will depend on the circumstances (already referred to) affecting reciprocal demand. It is conceivable that the home country, owing to its special facilities for production, may still obtain as large a quantity of imports, and as large a share of the 'total gain' as before. It is even possible that its imports and its gain from foreign trade may increase. But in view of the development of the industrial resources of the world and the improvement in means of communication, it is more probable that a disturbance might occur in some industries, and that the direction of foreign trade may be altered.

On the other hand, if the output be maintained after the reduction in hours and relative values remain unchanged, the course of foreign trade will tend to remain unaltered, since the amount of exports will not diminish, the home country having the same interest as before in continuing the exchange of commodities.

Professor Sidgwick has suggested that the characteristic of international trade is not the immobility of capital and labour, but the cost of carriage. Assuming that the exchange of commodities between nations is governed by cost of production, he regards the problem of international values to consist in the determination of the conditions that govern the division of cost of carriage between the countries concerned.[1]

Assuming this view, the effects of a reduction of hours on international trade would be similar to the effects on the home trade described in sections 2 and 3 of this paper. But the following special considerations arise :—

1. A reduction in net produce that might appear substantial measured with reference to exports would be much less if measured with reference to exports plus imports. We have seen that a reduction in hours will affect all trades and all producers; the greater the area over which the effects are spread the smaller the loss each industry will suffer.

2. But capital and labour are less inclined to migrate to foreign industries than to home industries; hence the economic equilibrium may be only partially adjusted and the chief loss may be thrown on the home country.

3. The cost of production being increased by the reduction in the hours of labour, foreign customers may find it to their advantage to buy elsewhere, and a portion of the foreign trade may be lost, or if retained, it will be by receiving in exchange a smaller amount of foreign goods.

The net produce would under such circumstances be reduced.

The cost of carriage would, for a time at least, tend to increase, inasmuch as a smaller amount of exports or of imports would require to be carried, and the probability is that this loss would fall on the country that reduced its hours of labour.

The main conclusions, then, at which we have arrived may be summed up as follows :—

1. That a reduction in the hours of labour which is neither universal nor uniform, will tend to reduce the net produce available for division amongst the producing classes, but such reduction may be lessened or counteracted by greater efficiency in labour and in the use of capital.

2. Capital will be able to throw a portion of the loss on labour, and labour generally will be affected.

3. That any check to the accumulation of capital due to the reduction in the net produce will tend to raise interest and lower wages, but this may be avoided to some extent by the more economic use of capital.

4. That the reduction in hours will not necessarily lessen the number of the unemployed, inasmuch as it will not increase the purchasing power

[1] *Political Economy*, Bk. II. c. iii.

of the consumer and will not affect the chief causes of poverty incident to our present organisation of industry.

5. That the position of the chronic unemployed or residuum will not be materially improved.

6. That in so far as additional labourers are employed to maintain the net produce, it will be at the expense of other workers, if the net produce remains the same but the number of producers increases.

It is necessary to point out that arguments which may be urged against a general though unequal reduction of hours do not apply with the same force to a reduction of hours in a particular trade that may be the subject of special economic surroundings. Before venturing to express an opinion on the desirability of reducing hours in a given industry, *e.g.* in mining, the economist will require to investigate these surroundings in order to estimate what loss, if any, will occur, and on whom such loss will fall.

But even if there be a loss in a particular industry or a national loss, it may be more than made good to the nation by the beneficial effects on the working classes of greater leisure. Hence the importance of asking what will the working classes do with the hours they gain from toil. Looking at the development of university teaching amongst the Northumberland miners, the progress of co-operation in Lancashire, the interest that is being developed in education, elementary, commercial, and technical, by trade unionists, and the increasing attention that the working classes are giving to the work of government, it is more than probable that, as far as the skilled industries are concerned, the workers would on the whole utilise additional leisure in a manner creditable to themselves and useful to the State.

APPENDIX.

(*a*) The employer will probably prefer to maintain production by the use of machinery, or of improved machinery, rather than by employing additional labour. On the introduction of the 'nine hours' into the engineering trades many employers maintained their output without employing additional hands.

(*b*) The owner of a factory handed it over to his son. At the end of a year he found that, owing to mismanagement, all profit was tending to disappear. He pensioned the son, employed a competent manager, and restored the business to former prosperity.

(*c*) That a reduction of hours in a skilled industry will not *per se* afford additional employment is borne out by the following figures relating to the engineering trades. In 1871 the hours of labour in the engineering trade varied from 60 to 54 per week, and the percentage of unemployed members of the Amalgamated Society of Engineers was 1·3. In the following year the hours were reduced to a number varying from 54 to 51 per week, the percentage of unemployed in the same society being 0·9. In 1875 a week of 54 hours was made universal. The number of members of the society and the number and percentage of unemployed members since 1872 have been as follows:

—	No. of Members	Average No. unemployed per Month	Average Percentage per Month
1872	41,075	397	0·9
1873	42,382	465	1·1
1874	43,150	674	1·6
1875	44,032	1,077	2·4
1876	44,578	1,627	3·6
1877	45,071	2,118	4·7
1878	45,408	2,974	6·5
1879	44,078	5,879	13·3
1880	44,692	2,646	5·9
1881	46,101	1,630	3·5
1882	48,388	889	1·8
1883	50,418	1,177	2·3
1884	50,681	2,591	5·1
1885	51,689	3,240	6·2
1886	52,019	3,859	7·4
1887	51,869	3,292	6·3
1888	53,740	2,239	4·2
1889	60,728	1,208	1·9

These figures show conclusively that the number of hours in a skilled industry may be reduced, and yet many workers in the industry may remain unemployed. A bad harvest, a commercial crisis, a hostile tariff, are examples of causes that affect employment; such causes would not be removed by a reduction in the hours of labour.

Fourth Report of the Committee, consisting of Dr. GIFFEN (*Chairman*), Professor F. Y. EDGEWORTH (*Secretary*), Mr. S. BOURNE, Professor H. S. FOXWELL, Professor ALFRED MARSHALL, Mr. J. B. MARTIN, Professor J. S. NICHOLSON, Mr. R. H. INGLIS PALGRAVE, *and* Professor H. SIDGWICK, *appointed for the purpose of investigating the best methods of ascertaining and measuring Variations in the Value of the Monetary Standard.*

YOUR Committee have further considered the matters referred to them, with special attention to the question as to the way in which the method of an 'index-number' for the prices of leading commodities, which they have found to be the best method of 'ascertaining and measuring variations in the value of the monetary standard,' may be applied in practice.

They have come to the conclusion that, in practice, what will have to be done, when opinion is ripe on the subject, will be, that Governments should appoint special commissions or direct existing departments of State to collect a sufficient number of prices officially, to publish these prices officially, to deduce one or more index-numbers from them, and to publish the variations in these index-numbers annually, or at more frequent periods if found desirable.

In doing so, it would be desirable that Governments should have regard to the theoretical principles explained in our previous reports, especially to the principle of weighting the different articles, of which the prices are to be obtained, according to their relative importance in the group or groups of articles for which index-numbers are to be formed. Probably it may be found, as a matter of convenience, that the best way in which this can be done practically is to place in a particular group two or more closely allied articles, according to the importance intended to be given to the generic article under which they may be described, as is done in fact in the Economist Index Number, which is often referred to, by means of several kinds of cotton articles counting each as one.

To save all question, however, we should also recommend that, in forming either a general or special index-number, the prices of a considerable number of articles should be obtained, for reasons which have been fully apparent in the previous reports and discussions that we have submitted.

We are unable, however, to recommend at the present stage what particular articles or groups of articles should be included in forming index-numbers for use in this country. We trust that the suggestions made in our previous reports will be found useful by any Government in taking up the subject, but in the present state of information as to the relative importance of articles, as to the prices it may be possible to obtain, and as to the practical objects which Governments would have in view in forming index-numbers, we do not think it practicable to go into detail on this head. At the same time, it is not in our power to make the requisite inquiry, which can only be carried out by Governments, and will not, of course, be undertaken by Governments until there is a sufficient body of practical opinion in favour of index-numbers.

What we should recommend first of all would be that the importance of obtaining systematically and regularly more prices than are now obtained should be pressed on the Government, and that the principle of the Corn Returns Acts, under which the prices of grain have been obtained for more than a hundred years in England, by means of records of actual sales systematically collected, should be more extensively applied.

Were there more of such official prices, their practical utility in many ways would soon become obvious, and it would be easy for individuals to make index-numbers of their own, which would prepare the way for official index-numbers. As matters stand at present, the way is being prepared to some extent by the habit of using index-numbers—such as those of the Economist, Mr. Sauerbeck and Dr. Soetbeer—which is steadily growing, but the use of a larger number of official prices would conduce further to the same end.

We doubt if it would be expedient at the present stage to press very strongly for the actual appointment of a Government Royal Commission or Parliamentary Committee with a view to make the necessary inquiries as to what statistics of prices should be obtained, in order to the immediate formation of one or more index-numbers. We hardly think that opinion generally is ripe enough for such a step being taken. But the exigencies of such public discussions as those engaged in by the Royal Commissions on Trade Depression and on Gold and Silver, and which have been going on with reference to the Tithe Settlement of 1836, will possibly lead before long to the question becoming immediately practical, and there would be room at present, or very soon, we believe, for a small committee, under one of the Government Departments, such as the Board of Trade or the Treasury, to prosecute an inquiry of the nature suggested. It will be expedient, however, to defer any further practical action until opinion is more ripened. The main thing to get into the public mind is the notion that a monetary 'standard' is itself a thing whose variations may require measuring for various practical purposes. And, although the idea is getting more about than was the case ten or twenty years ago, and is admitted theoretically, it is not yet so well understood generally among our leading public men that practical action can be considered immediately possible.

With a view still further to stimulate discussion and prepare public opinion, we propose to append to this report a draft of an Act of Parliament, which was originally submitted to us by the Chairman, and on which various amendments have since been made at the suggestion of members of the Committee. This draft, Mr. Giffen informs us, is modelled on the provisions of the Corn Returns Acts. It will be understood that it is merely the sketch of an Act which may become possible when opinion has further ripened. The method of a weighted index-number is not expressly referred to in it, neither is a first list of articles included such as would not improbably be specified in any such Act when legislation becomes actually possible. But it must be understood that the principle of a weighted index-number is adhered to by the Committee as expressed in their previous reports, although it is not explicitly given effect to in the appended sketch.

In conclusion, the Committee would summarise the results they have arrived at in their present report as follows:—

1. That our work as to the theoretical issues raised is now fairly complete.

2. That a further inquiry is needed as to the best way of obtaining the requisite statistics, and that it is beyond our power to conduct such an inquiry.

3. That it would be expedient, when public opinion has further ripened, that a Royal Commission or a Departmental Committee be appointed to undertake this task and report on it.

4. That meanwhile Government should be stimulated to obtain and publish more official prices than they do.

5. That the statistics which are ultimately collected should be used in the formation of several official index-numbers, each of which should be specially adapted for some particular purpose, and that they should be published in detail so as to be available for use by private persons in the affairs of business and in statistical inquiry.

6. That the general method to be adopted should be that of 'the weighted mean,' but that we have not at present sufficient information as to the number and accuracy of the statistics of prices, and volumes of production and consumption, that will be procurable for the purpose of enabling us to make a more detailed report. Our views as to the aims to be pursued, the practical importance of those aims, the difficulties to be encountered, and the best methods of dealing with those difficulties—so far as they are of a theoretical nature—have been sufficiently indicated in our earlier reports.

7. In case it should be found impracticable to get approximate 'weights,' a reasonably good makeshift would be found by selecting twenty important representative commodities and averaging their variations without weighting them.

By way of suggesting the direction which legislation might take on this last supposition, the Committee append to their report a proposal for an official index-number originally drawn up by Mr. Giffen, and on which various amendments have since been made.

DRAFT PROPOSAL FOR AN OFFICIAL INDEX-NUMBER.

1. Appoint a Special Commission to collect prices of such principal articles of production and consumption as may, from time to time, be directed by Order in Council.

2. Commission to have power to appoint inspectors of prices in towns, markets, and other places; and to direct by Order in Council that persons buying and selling in these towns, &c., such articles as may be prescribed, are to make returns in the prescribed form to the inspector so appointed or direct to the Commission.

3. Such persons failing to make a return, or making a false return, to be liable to a penalty of 20*l.* on conviction, &c.

4. The Commission shall publish, from time to time, in the *Gazette*, in prescribed form, the prices so obtained.

5. The Commission shall also publish on January 1 next, or on such other date as may be fixed by them after the commencement of this part of the Act, upon such evidence as shall appear to them satisfactory, a statement of the average prices of each of the specified articles for the ten years immediately preceding, and for each of these years; and the prices so declared shall be taken to be the par prices for the purpose of this Act.

6. In January of each year following, the Commission shall publish the prices for the previous year for the same articles as ascertained in the manner prescribed by the Commission under this Act; and shall also publish in the prescribed form a table of the proportion of these prices to the par prices, each of the par prices being reckoned for this purpose as 100, and the proportion in each case being stated in the form of the proportion to a hundred. The sum of these proportions shall also be stated. The table may be divided into parts, and the sum of the proportions in each part stated separately. The sum of the par prices, each reckoned as 100, shall be called the par index-number, and the sum of the proportions in each year shall be called the proportionate index-number for each year; and the sum of the par prices for each part, and of the proportions in each year, shall be called the par index-number, and the proportionate index-number for each part.

7. It shall be lawful in all contracts for payments in money to express that the payment is to be made for a given year in the proportionate index-number for that year, either for the whole of the said table or for a part of it, and thereupon payment may be made in such sum of sterling money as will correspond in respect of the sum contracted to be paid to the proportion which the proportionate index-number bears to the par index-number. It shall also be lawful in all such contracts to agree that the actual payment to be made in a given year shall be a sum of sterling money, bearing the same proportion to the sum named in the contract as the proportionate index-number for the said year bears to the proportionate index-number for the year in which the contract was made.

8. New articles may be introduced into the list and the table, from time to time, by Order in Council, which order shall declare the par price and index-number, and thereupon the amended list and table shall be used for all purposes as if it were the original list and table.

Report of the Committee, consisting of Dr. J. H. GLADSTONE (*Chairman*), Professor ARMSTRONG (*Secretary*), Mr. STEPHEN BOURNE, Miss LYDIA BECKER, Sir JOHN LUBBOCK, *Bart.*, Dr. H. W. CROSSKEY, Sir RICHARD TEMPLE, *Bart.*, Sir HENRY E. ROSCOE, Mr. JAMES HEYWOOD, *and* Professor N. STORY MASKELYNE, *appointed for the purpose of continuing the inquiries relating to the teaching of Science in Elementary Schools.*

IN presenting the report for the present year, your Committee have to record with great regret the death of Miss Lydia Becker, who has been a member of this Committee from its first appointment, and has always taken an active part in its proceedings.

While in some former years your Committee have had to chronicle a decreasing attention to Elementary Science in the schools, and futile attempts of the Legislature to improve education, they are able this year to speak of good promise, if not of actual progress.

The return of the Education Department, issued this spring, shows a slight turn of the tide in 1888–9. The following are the statistics of the class subjects as compared with the six previous years :—

Class Subjects.—Departments	1882–3	1883–4	1884–5	1885–6	1886–7	1887–8	1888–9
English . . .	18,363	19,080	19,431	19,608	19,917	20,041	20,153
Geography . . .	12,823	12,775	12,336	12,055	12,035	12,058	12,171
Elementary Science .	48	51	45	43	39	36	36
History . . .	367	382	386	375	383	390	386
Drawing . . .	—	—	—	240	505	—	—
Needlework. . .	5,286	5,929	6,499	6,809	7,137	7,424	7,620

The number of scholars examined in the scientific specific subjects are as follows :—

Specific Subjects.—Children	1882–3	1883–4	1884–5	1885–6	886–7	1887–8	1888–9
Algebra . . .	26,547	24,787	25,347	25,393	25,103	26,448	27,465
Euclid and Mensuration . . .	1,942	2,010	1,269	1,247	995	1,006	928
Mechanics A . .	2,042	3,174	3,527	4,844	6,315	6,961	9,524
„ B . .	—	206	239	128	33	331	127
Animal Physiology .	22,759	22,857	20,869	18,523	17,338	16,940	15,893
Botany . . .	3,280	2,604	2,415	1,992	1,589	1,598	1,944
Principles of Agriculture . . .	1,357	1,859	1,481	1,351	1,137	1,151	1,199
Chemistry . . .	1,183	1,047	1,095	1,158	1,488	1,808	1,531
Sound, Light, and Heat	630	1,253	1,231	1,334	1,158	978	1,076
Magnetism and Electricity . . .	3,643	3,244	2,864	2,951	2,250	1,977	1,669
Domestic Economy .	19,582	21,458	19,437	19,556	20,716	20,787	22,064
Total . .	82,965	84,499	79,774	78,477	78,122	79,985	83,420
Number of scholars in Standards V., VI., and VII.	286,355	325,205	352,860	393,289	432,097	472,770	490,590

It will be seen that there is a considerable increase in Mechanics A, due, no doubt, to the fact that this subject has been the one selected by some of the largest School Boards in the kingdom to be taught by their peripatetic science demonstrators. There has also been a marked proportionate increase in Botany over the last two years. Algebra and Domestic Economy have about held their own, while Animal Physiology, Chemistry, and Magnetism and Electricity show a considerable actual decrease.

The general result has been that the very serious annual decrease in the percentage of children taught these specific subjects as compared with the number that might have taken them has been arrested, or rather shows a fractional improvement.

In 1882–3	29·0 per cent.
„ 1883–4	26·0 „
„ 1884–5	22·6 „
„ 1885–6	19·9 „
„ 1886–7	18·1 „
„ 1887–8	16·9 „
„ 1888–9	17·0 „

The New Code.

The principal feature of this year has been the introduction of a code of regulations by the Education Department which makes many reforms in education, some of which refer to the teaching of science. The Code was generally accepted by both sides of the House of Commons.

This Code provides that science and manual instruction are recognised subjects 'in making up the minimum time constituting an attendance . . . whether or not they are given in the school premises or by the ordinary teachers of the school, provided that special and appropriate provision . . . is made for such instruction.' This gives official sanction to the teaching of these subjects in centres, or by the peripatetic system.

It does away with the restriction, of which your Committee have so long complained, that if class subjects be taken in a school, one of them must be English—an arrangement that virtually excluded the teaching of Elementary Science.

There is, however, the restriction that specific subjects cannot be taken unless the larger of the two principal grants was obtained at the preceding inspection. This is objectionable, as it is often in those very schools where literary excellence is difficult to attain that a knowledge of Mechanics, or the Principles of Agriculture, or Domestic Economy would be most valuable; and these could not be taken, unless, indeed, as class subjects.

In the appendix are inserted the new schedule of Elementary Science, and the alternate courses for that subject and for Geography. In the arrangement of these three members of your Committee were more or less consulted. It will be seen that the model course of Elementary Science in Schedule II. is made complete, and that several alternate courses are suggested which are essentially the specific subjects of Schedule IV. extended over five years, with object lessons bearing upon each subject for the two preceding years. It will be seen also that in the alternate courses for Geography the first is especially physical, the second specially commercial, while the third runs through only the first four standards, and the fourth is arranged to be taught in three divisions in order to adapt it to small schools in which the average attendance does not exceed sixty.

In the Revised Instructions to her Majesty's Inspectors it is stated that 'in sanctioning any modification of the printed schemes it will be necessary to have regard to the experience and qualifications of the teacher, and to any special opportunities afforded in the town or district for instruction by a skilled demonstrator, who visits several schools in succession, or who gives collective lessons at suitable centres.'

The general scheme of these schedules will greatly encourage and facilitate the taking up of these subjects, but the members of your Committee who are practical teachers of science are not satisfied with the final form in which they appear. They disapprove of the way in which object lessons in Standards I. and II. are treated, and especially that in the alternate courses they are made so closely connected with the special science which is to occupy the learners' attention in the later standards. They also disapprove of many details of arrangement in the respective standards; and of the minute subdivision in the schedule of sciences which are closely related to one another. The National Association for the Promotion of Technical Education endeavoured to get some modifications of these schedules, and drew up an alternative scheme of three courses in which the specialisation began at the Fourth Standard. None of these suggested improvements, however, appears in the 'Minute of the Committee of Council on Education modifying certain provisions of the new Code (1890),' which was passed on July 11. This minute, however, contains two clauses which will have an important bearing on the teaching of science. The first allows scholars who have passed the Seventh Standard, but are under fourteen years of age, to be retained on the school rolls and to count in the average attendance. The second rescinds the prohibition against presenting scholars in specific subjects in any school which in the preceding year failed to obtain the principal grant of 14*s*., unless such failure was due to other causes than that of the scholars not having been satisfactorily taught recitation.

In the specific subjects contained in Schedule IV. the principal alterations are the dropping of the alternative course in Mechanics, which was mainly theoretical and was rarely taken, and the separation of Mensuration from Euclid.

The alterations in the Code with regard to evening schools are important, and, as far as they go, are in accordance with the proposals of the Council of the British Association in 1881. These are, the rescinding of the requirement that scholars in the evening schools must be presented for examination in Reading, Writing, and Arithmetic, so far as those that have passed the Fifth Standard are concerned; and of the requirement that if special subjects are taught English must be one. Those scholars who have already passed Standard V. in the day school may be presented for examination in not less than two and not more than four of the special subjects. The omission of the elementary subjects has necessitated the passing of a small Bill through Parliament to legalise the making of grants to schools where elementary instruction was not the principal part of the instruction given. This Bill of Sir William Hart Dyke, which passed without opposition, opens the way for a considerable extension of natural science teaching.

There is still, however, one serious omission in the Code—the want of any stipulation that pupil teachers shall receive instruction in some branch of Natural Science. It still remains the case, as has already been pointed out, that a pupil teacher may gain a Queen's Scholarship without any acquaintance with scientific subjects. This is the more anomalous as pupil teachers are very frequently called upon to give object lessons in the schools to which they are attached.

The Code, it is true, gives this encouragement, that marks are given at the Queen's Scholarship Examination to pupil teachers and other candidates who have passed in one scientific subject at a previous Science and Art Examination; and last year 853 males and 559 females, out of 1,774 males and 2,453 females, received credit for having passed in some branch of science. This is a considerable advance upon previous years; but still it represents barely half of the male, and less than one-fourth of the female, teachers.

Scotland.

Some very important changes have been made in the Scotch Code of this year affecting the teaching of science, and apparently in an adverse direction. The former regulation, that if any class subjects are taken one must be English or Elementary Science, has been abrogated, and now teachers are left at liberty to choose any three or less of the recognised subjects, which are, English, Geography, History, Needlework for girls, Elementary Science. The scheme for this last-named subject, which was almost identical with that of the English Code, has been expunged, so far as the upper standards are concerned, and a tripartite course is given for Elementary Science for Standard III. and upwards, in the Animal Kingdom, the Vegetable Kingdom, and General Physics; and it is recommended that the three divisions of the subject should be taken in rotation. The schedule is given in Appendix II. According to the last report of the Committee of Council on Education in Scotland, of 3,113 boys and girls' departments, class subjects were taken in 3,048. Of these, 2,941 took the joint subject of History and Geography, and 107 took Elementary Science;—a considerably larger proportion than in England and Wales.

As regards the specific subjects, the whole of the more strictly scientific subjects—Mechanics, Chemistry, Animal Physiology, the two branches of Physics (Light and Heat, Magnetism and Electricity), Physical Geography, and Botany—have been entirely dropped, leaving only Mathematics, Principles of Agriculture, and Domestic Economy (girls). It is true that the Department proposes that 'instead of specifying a limited choice of subjects, with strictly prescribed courses of instruction, we have given to school managers the most complete freedom in suggesting subjects which they deem suitable to the requirements of their own locality, and in drawing up, for approval, schemes under which instruction in these subjects may be given;' but it remains to be seen whether they will take advantage of this liberty, and whether the number of scholars who were examined last year in Physical Geography (21,686), and in Animal Physiology (7,786), will not be considerably diminished in the future.

Ireland.

The fifty-sixth Report of the Commissioners of National Education in Ireland gives a very interesting account of the practical teaching that is introduced into the National Schools of Ireland. There is a large amount of manual instruction, and the rudiments of technical education. The teaching of Agriculture is obligatory in country schools for children above the Third Class or Standard, and 50,143 out of a possible 183,065 passed in this subject. It is interesting also to know that all children above the Second Class go through a course of instruction in Geography.

Science and Art Department.

Although the Code allows manual instruction to be put on the time-table of Elementary Schools it does not provide for any Parliamentary grant. The Science and Art Department, however, have resolved to give a grant of 6*s*., or if excellent of 7*s*., for every scholar, subject to the following conditions:—

'3. The instruction must be—

(*a*) in the use of the ordinary tools used in handicrafts in wood or iron;

(*b*) given out of school hours in a properly fitted workshop;

(*c*) connected with the instruction in drawing; that is to say, the work must be from drawings to scale previously made by the students.

'4. The instruction may be given by one of the regular teachers of the school if he is sufficiently qualified; if not, he must be assisted by a skilled artisan.

'5. The work of the class will be examined by the local Inspector of the Department, accompanied if necessary by an artisan expert, on the occasion of his visit to examine in drawing.

'6. If it appears that the school is properly provided with plant for instruction, and that the teaching is fairly good, a grant of 6*s*., or if excellent of 7*s*., will be made for every scholar instructed, provided (*a*) that he has passed the Fourth Standard; (*b*) that he has received manual instruction for at least two hours a week for twenty-two weeks during the school-year; (*c*) that a special register of attendance is kept; and (*d*) that each scholar on whom payment is claimed is a scholar of the day-school and has attended with reasonable regularity. The grant may be reduced or wholly withheld at the discretion of the Department, if it appears that the plant is insufficient, or that the instruction is not good.' As, however, the provision that this instruction should be given 'out of school hours' is inconsistent with its being put upon the time-table, and interfered seriously with the arrangements for teaching in centres, strong representations were made to the authorities, and a new circular was issued, stating 'that the restriction in Section 3 (*b*)—that the manual instruction shall be given out of school hours—does not prevent this instruction being included in the time-table of the school; provided that the time devoted to manual instruction by any scholar, for the purposes of the grant from the Department of Science and Art, does not include any part of the two consecutive hours of instruction in the subjects of the English and Scotch Codes requisite to constitute an attendance; or of the four hours a day secular instruction requisite under the rules of the Commissioners of National Education in Ireland.' This explanation, however, fails to remove the difficulties that are felt in practically carrying out this manual instruction.

The Science and Art Department have also issued a circular, stating, among other things, that 'after the examinations this year no pupil on the register of an elementary school receiving aid from the English or Scotch Education Departments or from the Commissioners of National Education in Ireland may be presented for examination by the Department of Science and Art, or registered as a student in any subject of science in a science class under that Department.' This would have been extremely injurious to the higher elementary schools which have been established in many of the large provincial towns; and memorials were therefore presented pointing out the necessity of a modification. This led to the withdrawal of the paragraph quoted and the restoration of the paragraphs in the 'Science and Art Directory' (§ 16, p. 30, and § 12, p. 56) which were affected by it, 'with this modification, that no scholar of an elementary school may be presented for examination by the Department of Science and Art in any subject in which he has been examined since the preceding 1st August by the English or Scotch Education Departments for a class or specific subject grant, or by the Commissioners of National Education in Ireland for an extra branch fee.'

General Conclusion.

It will be seen that this year has been fruitful in legislative and administrative changes that bear upon the teaching of science in elementary schools. They have generally met with the approval of those educationists who are interested in science and its applications, but it has yet to be seen how far they may be practically adapted to the purpose in view.

APPENDIX I.

Elementary Science.

Standard I.	Standard II.	Standard III.
Thirty lessons on common objects, e.g.— A postage stamp; the post; money; a lead pencil; a railway train; Foods and clothing materials, as bread, milk, cotton, wool; Minerals; natural phenomena, as gold, coal, the day, the year.	Thirty lessons on common objects, such as animals, plants, and substances employed in ordinary life, e.g.— Horse Leaves Sparrow Candles Roots Soap Stems Cork Buds Paper	Simple principles of classification of plants and animals. Substances used in the arts and manufactures. Phenomena of the earth and atmosphere.

Standard IV.	Standard V.	Standard VI.	Standard VII.
A more advanced knowledge of special groups of common objects, such as— (*a*) Animals, or plants, with particular reference to agriculture; or (*b*) Substances employed in arts and manufactures; or (*c*) Some simple kinds of physical and mechanical appliances, e.g. the thermometer, barometer, lever, pulley, wheel and axle, spirit level.	(*a*) Animal or plant life; or (*b*) The principles and processes involved in one of the chief industries of England; or (*c*) The physical and mechanical principles involved in the construction of some common instruments, and of some simple forms of industrial machinery.	(*a*) Animal and plant life; or (*b*) The commonest elements, and their compounds; or (*c*) The mechanical powers.	(*a*) Distribution of plants and animals, and of the races of mankind; or (*b*) Properties of common gases; or (*c*) Sound, or light, or heat, or electricity, with applications.

SUPPLEMENT TO SCHEDULE II. ALTERNATIVE COURSES.—CLASS SUBJECTS.

The scheme marked S is intended for small schools in which the average attendance does not exceed 60.

Geography.

—	Standard I.	Standard II.	Standard III.	Standard IV.	Standard V.	Standard VI.	Standard VII.
Course A . .	Plan of school and playground. Meaning and use of a map. The cardinal points.	Size and shape of the world. Geographical terms simply explained. Physical geography of hills and rivers, illustrated by reference to the map of England.	Physical, political, and industrial geography of England, with special knowledge of the district in which the school is situated.	Physical and political geography of Scotland and Ireland and of the United States of America. Day and night. The air, mists, fogs, clouds, rain, frost, wind, and the special circumstances which determine climate and rainfall in the British Islands.	Physical and political geography of Europe. Industries and productions of its several countries. Latitude and longitude. The seasons.	Physical and political geography of Australia, New Zealand, Canada and the South African colonies, India and Ceylon. Climate as affected by latitude, altitude, rainfall, forests, nearness to the sea, ocean currents, and prevailing winds.	The general arrangement of the planetary system. The sun. The moon and its phases. The tides. Eclipses.
Course B . .	Plan of school and playground. Meaning and use of a map. The cardinal points.	Home geography, e.g. roads, rivers, and chief buildings of the district, illustrated by a map, and by the map of England.	General geography of England and Wales, and means of communication by land and water. Chief industries and productions of the district in which the school is situated.	General geography of Scotland, Ireland, Canada, and the United States, with special reference to the interchange of productions between those countries and England.	General geography of Europe, with special reference to the commercial relations between the countries of the Continent and Great Britain.	General geography of Australia and British India, with special reference to the industries of those countries, and to their commercial relations with Great Britain. Colonisation.	General geography of Asia and Africa, with special reference to their productions and trade. Colonisation and the conditions of successful industry in British possessions generally.
Course C. Geography and History combined.	Plan of school and playground. Meaning and use of a map. The cardinal points.	The size and shape of the world. Geographical terms simply explained and illustrated by reference to the map of England. Physical geography of hills and rivers.	Physical and political geography of England, with special knowledge of the district in which the school is situated.	Geography of Europe generally, and of either Canada or Australia.	Ten stories and biographies from English history before the 16th century. The Tudor period. The constitution and functions of Parliament.	The Stuart period. Acquisition of territory during this period. Constitution and functions of courts of justice. Taxation.	The Hanoverian period, with special reference to— (1) Acquisition and loss of territory during this period. (2) Chief legislative Acts. (3) Biographies of six distinguished writers.

—	Standards I. and II.	Standard III.	Standards IV., V., VI., VII.
Course S . .	The cardinal points. Use of a plan and map, with illustrations of geographical definitions.	Geography of England, with special knowledge of the district in which the school is situated.	Outlines of the world, with special knowledge of neighbouring countries or commercial and colonial interests.

SUPPLEMENT TO SCHEDULE II.

Elementary

Any of the following alternative courses may be chosen in schools in which the same subject is not taken up as a specific subject. The courses should be taught throughout the school by means of conversational object lessons in the lower standards, and more systematic instruction with the aid of text-books in the higher standards.

The object lessons given in Standards I. and II. should include, in Mechanics, Botany, and Physics, some lessons on the phenomena of nature and of common life; in Physiology, on the external structure and habits of animals; in Agriculture, on food substances, familiar animals, and common plants; in Domestic Economy, on the principal substances used for food and for clothing. Specimens of a few such topics are given.

—	Standards I. and II.	Standard III.
Course A. Mechanics .	Thirty object lessons, e.g.— A pair of scales. A pair of bellows. A hammer. A clock. Carriage wheel. Building of a house. Iron and steel. Gold.	Matter in three states: solids, liquids, and gases.
Course B. Animal Physiology.	Thirty object lessons, e.g. on the external structure and the habits of common animals.	The build of the human body.
Course C. Botany . .	Thirty object lessons, e.g.— Tea. Sugar. Coffee. Cabbage. Carrot. Potato.	Characters of the root, stem, and leaves of a plant, illustrated by common flowering plants.
Course D. Principles of Agriculture.	Thirty object lessons, e.g.— The usefulness of the various animals kept on a farm, and how they repay kindness and care. Bees. Earth-worms. A grain of wheat. Hay. Work in a forge. The work to be done on a farm in the different seasons. Gardening. Garden tools.	The supply of plant food in the soil.
Course E. Chemistry .	Thirty object lessons on familiar objects, e.g. of the inorganic world.	Properties of the common gases, such as oxygen, hydrogen, nitrogen, and chlorine.
Course F. Sound, light, and heat.	Thirty object lessons, e.g.— Bell. Trumpet. Tuning fork. Sunlight. Primary colours. Candle. A fire. Boiling water. Red-hot poker.	The three modes in which heat may be conveyed from place to place.
Course G. Magnetism and electricity.	Thirty object lessons, e.g.— Amber. Glass. Sealing-wax.	Attraction, repulsion, and polarity, as illustrated by the magnet. Mariner's compass.
Course H. Domestic Economy (girls).	Thirty object lessons on materials used for food, e.g.— Flour. Meat. Vegetables. Tea. Coffee. Milk. Fruits. Salt.	Chief materials used in clothing and washing, e.g.— Silk. Linen. Wool. Cotton. Fur. Leather. Washing materials.

ALTERNATIVE COURSES—*continued.*

Science.

If two standards are grouped together, the portion given to the lower standard may be taken one year, and that assigned to the higher standard in the next year, in cases where this is practicable and consistent with the relation between the two portions; or the two portions may be taken in outline one year, and more fully in the next year.

It is intended that the instruction in Elementary Science shall be given mainly by experiment and illustration. If these subjects are taught by definition and verbal description, instead of by making the children exercise their own powers of observation, they will be worthless as means of education. The examinations by the inspectors will be directed so as to elicit from the scholars, as far as possible in their own language, the ideas they have formed of what they have seen.

Standard IV.	Standard V.	Standard VI.	Standard VII.
The mechanical properties peculiar to each state. Matter is porous, compressible, elastic.	Measurement as practised by the mechanic. Measures of length, time, velocity, and space.	Matter in motion. The weight of a body; its inertia and momentum.	The lever; the wheel and axle; pulleys; the inclined plane; the wedge; the screw. The parallelogram of velocities. The parallelogram of forces. Examples commonly met with illustrating the mechanical powers.
Names and positions of the chief internal organs of the human body.	The properties of muscle. The mechanism of the principal movements of the limbs and of the body as a whole.	The organs and functions of alimentation, circulation, and respiration.	The general arrangement of the nervous system. The properties of nerve. Sensation.
Characters of the parts of the flower, illustrated by common flowering plants.	The formation of different kinds of fruits. Cells and vessels.	Functions of the root, leaves, and different parts of the flower. Food of plants, and manner in which a plant grows.	The characters of the larger groups and most important families of flowering plants. The comparison of a fern and a moss with a flowering plant.
The necessity for cultivation, and the circumstances making tillage more or less effective.	The principles regulating the more or less perfect supply of plant food.	Manures as supplemental sources of plant food, and recapitulation of the course for Standard V.	The principles regulating the growth of crops, and the variation in their yield and quality.
The chemical character and constituents of pure air, and the nature of the impurities sometimes found in it.	The chemical character and constituents of pure water, and the nature of the impurities sometimes found in it.	The properties of carbon and its chief inorganic compounds. Non-metallic bodies.	Metallic bodies. Combination by weight and volume. The use of symbols and chemical formulæ.
Effects of heat on solids, liquids, and gases. Expansion by heat. The thermometer.	Propagation of light. Intensity, shadows. Reflection, mirrors; refraction, lenses.	Elementary explanation of the microscope, camera obscura, and magic lantern. Reflecting and refracting telescopes.	Propagation of sound. Elementary notions of vibrations and waves. Reflection of sound, echoes.
Attraction of light bodies by rubbed sealing-wax and glass. Experimental proof that there are two forms of electricity. Attraction and repulsion.	Gold-leaf electroscope. Construction of electrophorus, electrical machines, and Leyden jar.	Voltaic battery and notions of a current. Magnetic effect of a current. Galvanometer. Electro-magnets.	Terrestrial magnetism. Chemical effect of a current. Electrolysis. Induced currents. The electric telegraph.
Food: its composition. Clothing and washing.	Food and beverages: their properties and nutritive value and functions. The skin and personal cleanliness.	Food: its preparation and culinary treatment generally. The dwelling—Warming. Ventilation. Cleaning.	Food: simple dishes. Rules for health. Common ailments and their remedies. Management of a sick-room.

APPENDIX II.

SCOTLAND.

Elementary Science Schedule.

(*a.*) ANIMAL.—St. III. General notions of the differences of structure of beast, bird, fish, insect, and reptile.
St. IV. Classification, with habits and uses.
St. V. (Man.) Circulation, respiration, and alimentation.
St. VI. (Man.) Bones, muscle, brain, nerves; the organs of sight, smell, touch, hearing, and taste.

(*b.*) VEGETABLE.—St. III. Comparison of animal with vegetable life. General structure of a plant, root, stem, flower, with specimens.
St. IV. Plant structure. Wood, bark, pith, cells. Uses of different parts of a plant.
St. V. Food and growth of plants. Exogens and endogens. Formation of different kinds of fruit.
St. VI. Principles of classification, with a general knowledge of the chief orders. Germination, ferns, mosses.

(*c.*) MATTER.—St. III. Matter, organic and inorganic, elementary and compound. Its three interchangeable states, solid, liquid, gaseous. The properties of matter.
St. IV. Energy indestructible. Force, inertia, momentum, gravitation, cohesion, chemical affinity, combination and decomposition. Preparation and properties of oxygen, hydrogen, nitrogen, and chlorine.
St. V. Heat. What it is; effects of; modes of; thermometer. Reflection and refraction of light; dispersion of light by a prism. Microscope; telescope.
St. VI. Magnets; kinds, structure, uses. Mariner's compass. Electricity, kinds, laws; electroscope, electrophorus, telegraph. Lever, wedge, screw.

Fourth Report of the Committee, consisting of Mr. S. BOURNE, Professor F. Y. EDGEWORTH (*Secretary*), Professor H. S. FOXWELL, Mr. ROBERT GIFFEN, Professor ALFRED MARSHALL, Mr. J. B. MARTIN, Professor J. S. NICHOLSON, Mr. R. H. INGLIS PALGRAVE, *and* Professor H. SIDGWICK, *appointed for the purpose of inquiring and reporting as to the Statistical Data available for determining the amount of the Precious Metals in use as Money in the principal Countries, the chief Forms in which the Money is employed, and the amount annually used in the Arts.*

YOUR Committee, as stated in last year's report, anticipated that a good deal of light would be thrown on this subject by the experience gained in connection with the withdrawal of the pre-Victorian sovereigns and the arrangements which were made by Mr. Palgrave and Mr. Martin to count samples of the coinage in circulation and to ascertain the proportion of the pre-Victorian coinage to the total.

Messrs. Martin and Palgrave have informed the Committee, however, that they have not yet completed the investigations in which they have been engaged. As the information may become public through some other channel, and as no progress can be made in other directions, it will be for consideration whether the Committee need be continued.

On some New Telemeters, or Range-finders. By Professors ARCHIBALD BARR, *D.Sc., M.Inst.C.E., and* WILLIAM STROUD, *B.A., D.Sc.*

[Ordered by the General Committee to be printed *in extenso.*]

THE conditions of modern warfare have given rise to the requirement of efficient range-finders for artillery and infantry use and for coast defence. Such instruments are, however, not only indispensable for military purposes, but civil engineers have long felt the want of reliable telemeters, both for use in rapid survey work of a more or less rough and preliminary kind, and for making accurate measurements under conditions not favourable to the application of ordinary methods of surveying.

With a view of meeting these requirements a great variety of instruments have been devised, a few of which have been brought into use, and have proved more or less successful in practice. For coast defence may be instanced the position-finder of Major Watkin, in use in England, and that of Lieutenant Fiske, used in America; for artillery and infantry purposes the instruments of Watkin, Weldon, and Labbez; and among instruments for surveying purposes the stadiometer, tacheometer, and omnimeter.

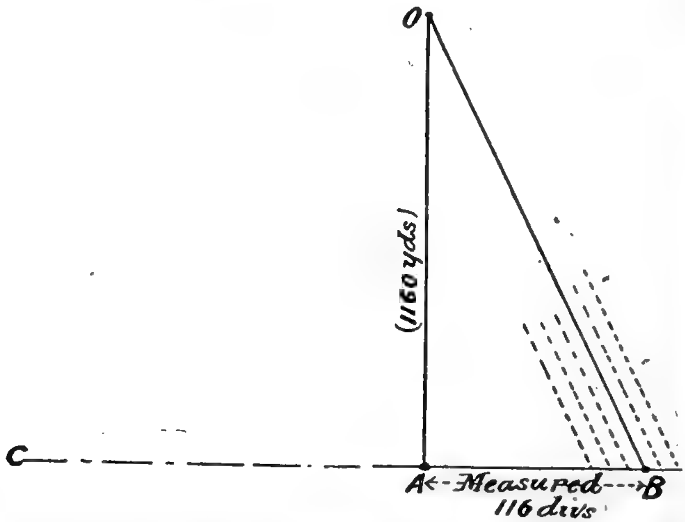
Instruments have been devised for military range-finding to indicate the distance of an enemy by a measurement of the time-interval between seeing the flash or smoke from one of his guns and hearing the report; but such a method of operation could not, for obvious reasons, serve all the purposes of military range-finding, and could not be relied upon for purposes either of attack or defence. Setting these aside, we may say that all range-finders and telemeters—properly so called—depend for their indications upon the measurement of the elements of a triangle, one of whose sides is the range to be determined. In nearly every case, too, the triangle to be solved is approximately right-angled, and the operation of determining the range of a point O from A (fig. 1) consists virtually in setting out the base A B, and measuring the angle subtended by it at O, or in setting out the angle at O and measuring A B. In such cases, as the side A B—which is referred to as the *base* of operation—is very small compared with the range O A (or O B), the distance of O from A (or B) will be expressed, with sufficient accuracy, by AB/α, where α = angle A O B in radian measure.

Telemeters naturally divide themselves into two classes —(1) those using a base of known or observed length at the distant object; (2) those working from a base of known or measured length at the observer's station. Instruments of the former class, using as base the distance between two marks (or the interval between two observed graduations) upon a staff held at the distant point (*e.g.*, the tacheometer and omnimeter), are, as a rule, the most accurate and convenient for surveying work when the distant point is accessible to a man carrying the base-staff. We hope on a future occasion to describe some new telemeters of this class which we have recently devised. Proposals have been made to determine the distance of an enemy by means of simple instruments working upon this principle, and using the height of a man in the enemy's ranks as a base; but besides the impossibility of getting reliable results, under the most favourable circumstances, with a base so ill-defined and so variable in length, it is seldom that observations of the kind required can be made at all under modern systems of warfare. The only range-finders suitable for general military purposes, therefore, belong to the second class.

Telemeters which utilise a base at the observer's station may, again, be divided into two sub-classes—(a) instruments having a short rigid base, and usually arranged to be operated by one observer, such as those of Adie, Christie, Mallock, and Haskett-Smith, and one recently brought out by the present writers; (b) instruments working from long bases, say 20 to 50 yards, and requiring two observers (or one observer observing successively from the two ends of the base), such as Weldon's, Lynam's, and Watkin's artillery and infantry range-finders. The three instruments which we are about to describe also belong to this division, to which we shall alone refer in what follows.

FIG. 1.

FIG. 2.



These long-base instruments may yet again be subdivided into two groups—(α) those using constant angles and variable base, such as the Weldon; and (β) those with constant base, one constant angle, and one variable angle, such as Watkin's and Lynam's infantry range-finders. Major Watkin's artillery range-finder practically belongs to this class as well, though it admits of the base being arbitrarily chosen within certain limits.

Colonel Weldon's instrument consists essentially of two triangular doubly-reflecting prisms, ground to give the angles at the base of a right-angled triangle of which the base is $\frac{1}{50}$ of the perpendicular (which is the range required). The mode of operation of this range-finder is illustrated in fig. 2. It is usually worked by one observer, who stations himself at A, and observes with the 90° prism what distant object at C appears reflected into coincidence with the object O. He then walks out along the line C A produced to B, where C appears in coincidence with O when using the second prism. The distance A B is then measured by a cord or tape marked at every two yards to represent hundreds of yards of range, and subdivided to indicate tens of yards.

Instruments of the constant-base and variable-angle type have hitherto usually consisted of an optical square, or instrument working on the sextant principle, with fixed mirrors for setting out a constant angle, and an instrument of the same kind with mirrors capable of relative motion for measuring the variable angle at the base of the triangle of observation. Each instrument has attached to it a prominent mark—in the form of a vertical white line on a black background—and when in use the instruments are connected together by a cord of, say, 25 yards in length. The optical square consists essentially of a pair of mirrors fixed at 45° to each other (see fig. 3); and the variable-angle instrument of a pair of mirrors similarly arranged at an angle of about 45° to each other, one of the mirrors, however, being capable of a slight angular motion relatively to the other.

In using range-finders of this class the chief observer, carrying the variable-angle instrument, takes up a fixed position at B (see fig. 4), while the assistant observer, carrying the optical square, moves round the

FIG. 3.

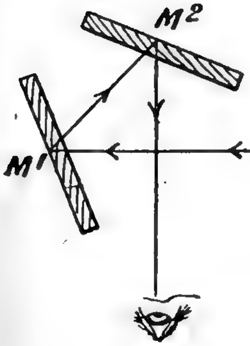
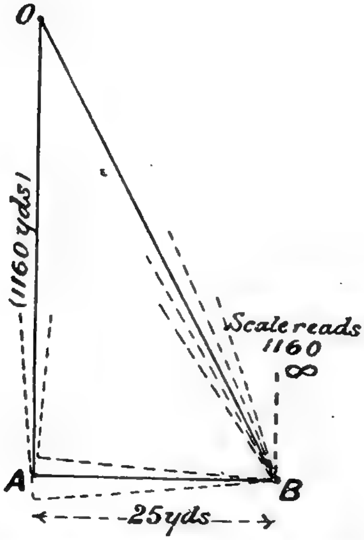


FIG. 4.



chief observer as a centre, keeping the base cord taut between the instruments, till he finds the point A from which he sees the chief observer's mark superimposed by reflection upon the distant object. When he has accomplished this adjustment of his position he informs the chief observer of the fact by shouting 'on'; the latter meanwhile operates the mechanism which alters the angle set out by his instrument till he brings the mark on the assistant observer's instrument into apparent coincidence with the distant object. The mechanism which operates the movable mirror also moves a scale, which indicates the distance of the object when correct alignment has been made by both observers. When the range of a moving object is being taken, the assistant observer must continuously shift his position so as always to set out a right angle between the chief observer's mark and the distant object. To do this with sufficient accuracy is not difficult when the enemy is approaching or receding in nearly a direct line to or from the observers, for the rate of change of direction of the base is then very slow. The difficulty is, of course, much greater when the enemy is moving rapidly across the field of view.

There would be no difficulty in constructing satisfactory instruments of this variable-angle class were it not for the fact that, the base being necessarily very limited in length compared with the ranges to be determined, the angles to be dealt with are exceedingly small, and consequently the slightest relative movement of the mirrors puts the instrument out of adjustment. Thus, let us assume that in the instruments themselves, independently of errors in observation and alteration in the length of the cord, there is not to be an error of more than 1 per cent. at 1,000 yards,[1] and that the base is 25 yards. This means that the angles must be set out correctly to about 50″; and since by reflection any angular shift of a mirror is doubled, a shift of any one of the four mirrors, or of these collectively, of more than 25″ is inadmissible. Moreover, the mechanism operating the movable mirror and scale must work correctly to 25″. This necessitates the use of micrometric devices of great delicacy. Such instruments are, therefore, not only liable to derangement by slight displacement of the mirrors, but micrometric arrangements, however perfect at first, are subject to wear and to rusting, especially under the conditions of actual service in the field, where they must necessarily be exposed to the damaging effects of rain and dust.

Colonel Weldon's instrument has a great advantage over instruments of the variable-angle class as hitherto made, in that it is incapable of derangement; but it has what appears to us to be the almost equally great disadvantage, that it is nothing like so facile in operation, especially for taking the range of an enemy in motion.

Our object in designing the range-finders we are about to describe has been to overcome the difficulties to which we have referred, and to combine the invaluable feature of non-liability to derangement with the facility of operation which is the characteristic of instruments based on the constant-base system. We believe that these three instruments are unique among constant-base range-finders in being quite incapable of optical derangement, whatever the treatment to which they may be subjected.

In each of the three range-finders at present to be dealt with, we use two instruments connected by a base-cord in the manner above described. The cord should, of course, be as inextensible as possible, and should not be subject to alterations in length through dampness. Fishing-line can readily be obtained very suitable for the purpose. Small variations in the length of the cord cause, however, no appreciable error—*e.g.* a variation of length of 1 inch in 25 yards will only affect the indication of the range by 1 part in 900.

The first of the three instruments is operated in the manner described with reference to other constant-base instruments, and illustrated in fig. 4. The instrument carried by the assistant observer is an optical square, but instead of being formed in the usual way of a pair of mirrors fixed at an angle of 45° to each other (fig. 3), it consists of a doubly-reflecting prism of a pentagonal form (fig. 5). The faces A B and B C are at right angles to each other, and the faces A B and C D, which are silvered, are inclined at 45° to each other. If the angles between these pairs of faces be exactly 90° and 45° respectively, then the prism forms a true optical square incapable of derangement. The course of a ray of light through the prism is represented in the figure. These prisms possess a great advantage

[1] This appears to us to be a large error to assume as allowable.

over the right-angled isosceles prisms (fig. 6) used in the Weldon range-finder, in that the field of view is very much larger.[1]

The difficulties of constructing such prisms so accurately that no error is perceptible is so great that we have had recourse to a very simple, expeditious, and cheap method of correcting them without regrinding. This consists in providing, in the path of one of the beams of light (either that passing through the prism from the mark upon the other instrument, or that of direct vision over or under the prism), a refracting prism of very small angle, rotating it in its own plane till the adjustment is perfect, and then fixing it securely in this position. This refracting prism may be cemented on to the face B C of the prism (fig. 5), but we prefer to fix it separately in front of the prism in the direct beam, as shown in fig. 7, where the angle of the prism is greatly exaggerated. It will be seen that when the prism is in the position shown by the full lines the angle set out will be the angle between the lines M F and H O′; whereas, when the prism is rotated through 180° in its own plane so as to be in the position

FIG. 5.

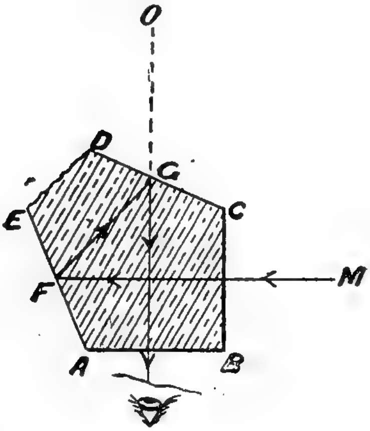
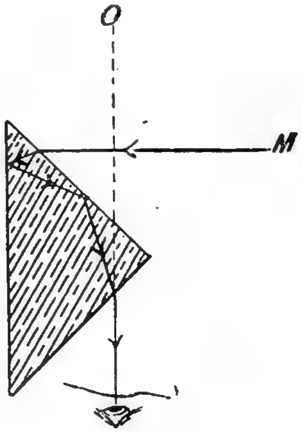


FIG. 6.



indicated by the dotted lines, the angle set out will be that between the lines M F and H O″. For intermediate positions of the refracting prism the angle set out will lie between those extremes. In this way the angle can be made 90° to any desired degree of accuracy. It must be understood that the angle of deviation of this refracting prism need never exceed a few minutes.

The variable-angle instrument, carried by the chief observer, is constructed in exactly the same manner, except that the refracting prism is of larger angle, and instead of fixing this prism in one position it is left free to be rotated relatively to the frame carrying the reflecting prism. The disc in which the refracting prism is held is provided with a scale marked upon its circumference, and an index is provided upon the frame in which the reflecting prism is fixed. The scale is marked to give the distance in yards of the object whose range is required.

The nature of the scale is indicated in fig. 8. It will be evident that a ray of light G H (supposed reversed in direction so as to proceed outwards from the eye to H) (fig. 7) will, after passing through the refracting prism,

[1] Such pentagonal prisms, we now find, have already been used for some time on the Continent.

be deviated from its course, as shown by H O′. When, however, the prism is rotated, this line will describe a cone, or, as projected upon the distant view, a circle, which fig. 8 may be taken to represent, the point Y corresponding to the position of the prism shown in full lines, and the point X to the position shown in dotted lines. The vertical motion of the image of the object viewed through the refracting prism is of no consequence, because the instrument may be directed up or down so as to observe upon any level. It will be evident that in this way 180° of angular rotation of the prism in its own plane might be utilised for setting out different angles by the instrument; but it is better to restrict the motion to something like 120° in all—60° on each side of the mean position of the prism when its thin edge is horizontal; this is shown in fig. 8, the motion of the prism being restricted by suitable stops, so that it cannot pass beyond the division 6 on the one side of the upper scale and the division 20 on the other side. This restriction of the motion possesses the advantage that the greater part of the horizontal shift produced by the prism is utilised, while the vertical motion is very little.

FIG. 7.

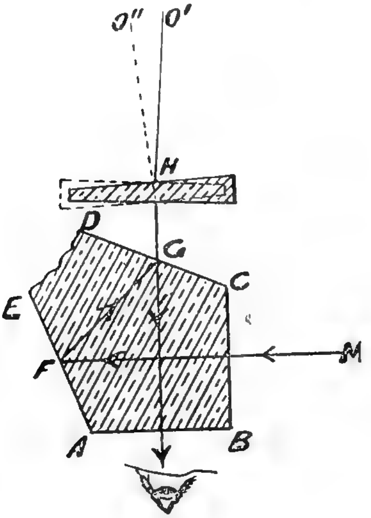
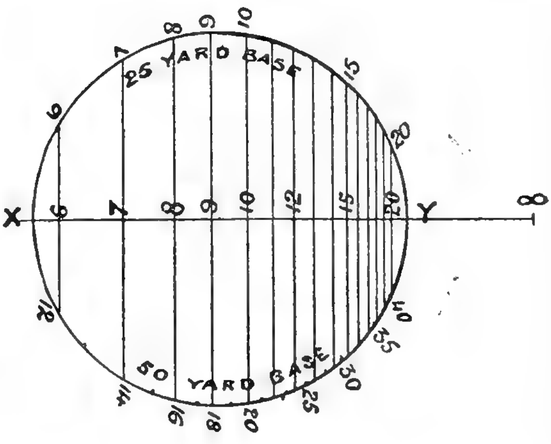


FIG. 8.



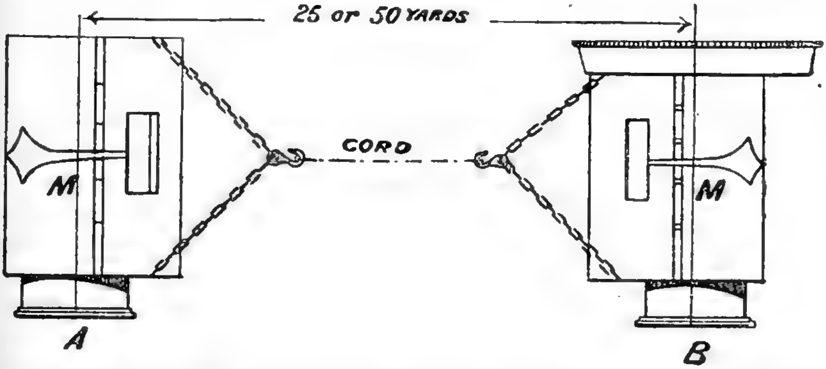
To understand the graduations of the scale it will be simplest to suppose that the marks on the two instruments and the distant object are in the same horizontal plane. If, then, the thin edge of the prism is horizontal, the angle set out by the variable-angle instrument will be simply that due to the reflecting prism, fig. 7; whereas, if the refracting prism be rotated from the previous position through an angle θ, the angle set out by the instrument will be different by an amount represented by $\pm\ \delta \sin \theta$, according to the direction of rotation, where δ represents the angle of deviation of the refracting prism. Let, then, A be the angle set out by the fixed instrument, and B that set out by the other instrument before the prism is introduced. Then for a position θ of the refracting prism (defined as above, and reckoned positive when it increases the angle set out by the instrument) the sum of the angles set out by the instruments will be $A+B+\delta \sin \theta$, and the supplement of this angle will be the angle subtended by the base of observation (of length b) at the distant object. The range will therefore be, for this position of the prism, and after the two observers have taken up their correct positions and the requisite coincidences have been effected, $\frac{b}{\pi - A - B - \delta \sin \theta}$.

Hence the equation $R = \frac{b}{\pi - A - B - \delta \sin \theta}$ could be utilised for purposes of graduation when the values of the constants A, B, δ, and b have been determined.

This question may, however, be looked at from a different standpoint. For constant-base range-finders the scale of ranges is naturally a scale of reciprocals, as is represented for another of our instruments in fig. 14. This scale of reciprocals is shown marked in fig. 8 on a horizontal line, and it is drawn by taking points marked 6, 7, 8, 9, &c., at distances from the mark ∞ proportional to $\frac{1}{6}, \frac{1}{7}, \frac{1}{8}, \frac{1}{9}$, &c. The sum of the angles set out by the two reflecting prisms (viz. A+B) determines with a particular base b a range $= \frac{b}{\pi - A - B}$. This range we have supposed to be 920 yards in drawing fig. 8. The point corresponding to 920 yards is to be taken as the centre of the circle of graduations. The radius of this circle will be dependent solely on δ, the angle of deviation of the refracting prism, and the particular base selected for observation. The distance, in fact, on the scale from ∞ to the point corresponding to $\frac{b}{\delta}$ will give the radius required. In fig. 8 this distance is that between the points ∞ and 15. With centre 920 and radius equal to this distance a circle has been described, and the points on the graduated circle have been so selected that their projections fall on the corresponding points on the horizontal reciprocal scale. By producing these lines downwards to meet the lower semicircle, and doubling the numbers to be read at each, a scale is obtained for a base of length $2b$.

The complete instruments are shown in figs. 9, 10, 11, and 12. Fig. 9 is a plan of the two instruments connected together by the cord, A being

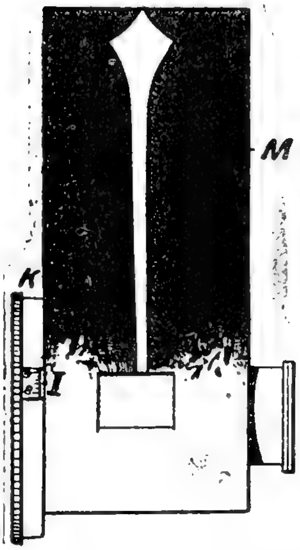
FIG. 9.



the assistant observer's instrument, and B the chief observer's instrument. The cord is attached to each instrument by two chains, whose lengths are adjusted once for all, so that when the instruments are pulled apart the chains direct them into such a position that the mark upon each instrument is brought into the reflected field of view of the other instrument. M M are the marks (white upon a black ground) which are seen in the plan on account of being placed sloping, as shown in fig. 11.

Fig. 10 is a side view of the chief observer's instrument as seen by the assistant observer. The upper part of the plate upon which the mark M is carried is hinged to the lower part for convenience in packing. Fig. 11 shows a sectional elevation, and fig. 12 a sectional plan of the chief observer's instrument, P being the reflecting prism and R the refracting prism. The latter is shown as constructed of crown and flint glass, so as to be achromatic. This is not necessary except for telescopic observation, but it possesses the advantage that, by rotation of the crown and the flint relatively to each other, the angle of deviation of the compound prism can be varied within certain limits, and so adjusted to a desired angle. The reflecting prism P is placed above the level of the centre of the instrument, so that a direct view is obtained below it through the refracting prism R. The prism P is rigidly fixed in the frame F by means of a very hard cement—almost as hard as the glass itself—so that relative rotation of the prism and the frame is absolutely impossible. The prism R is similarly rigidly fixed into the carrier C, a flat portion being ground off the circular prism, and its place in the carrier filled by a metal sector soldered in. The carrier C is supported in F so as to be free to rotate, and it is milled on the edge D to facilitate the rotation. S is the scale ring, graduated on the periphery, as above described; and indexes at I I serve to read the scales for the 25-yard base and the 50-yard base respectively. K is a piece which covers the scale except in the vicinity of the indexes.

FIG. 10.

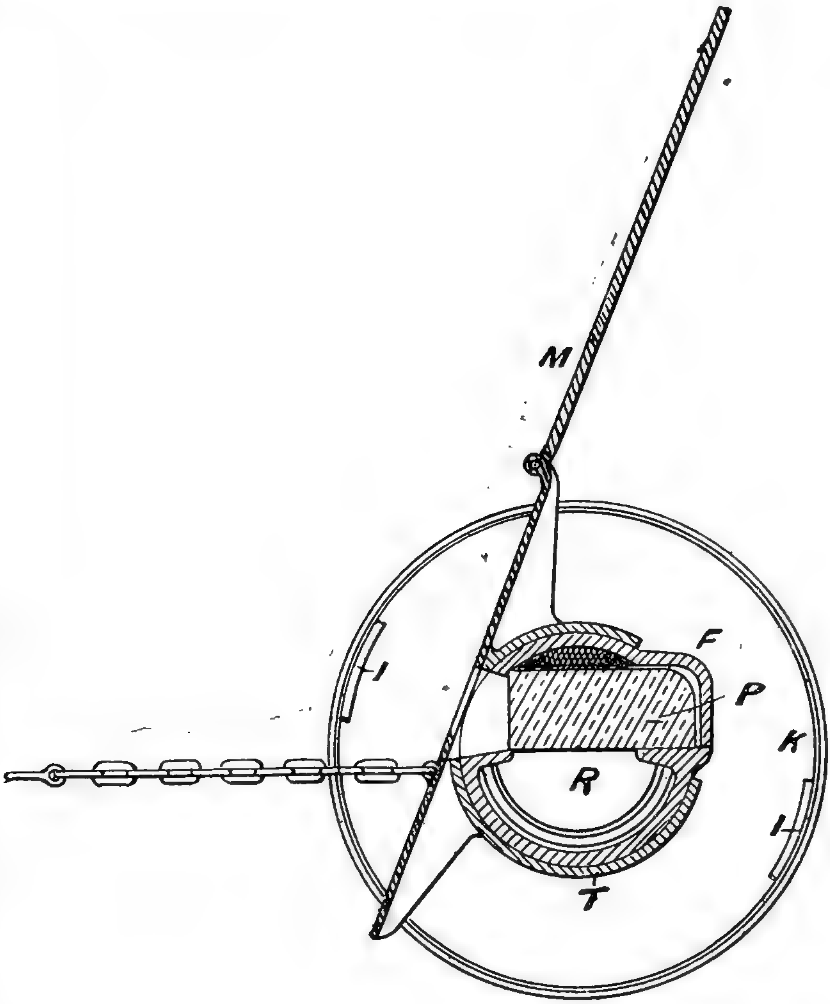


The construction of the frame F and carrier C is such that there are no openings by which dust or rain can get into the interior except through the small eye-hole E, and even this can be closed if thought desirable by a small piece of glass. The plate upon which the mark M is carried, together with the tubular piece T to which it is fixed, may be removed by unscrewing the eye-tube U, so that more convenient access can be had to clean the outer face of the prism P, for which purpose, also, the frame F is bevelled off at B.

It need hardly be pointed out that the angle of deviation of the prism R cannot be altered by accident or by use, neither can the angle set out by the prism P be altered. Moreover the prism R is rigidly fixed to the scale-piece, so that relative motion is quite impossible; and the prism P is fixed into the frame F, upon which the indexes are marked, so that relative rotation between these is impossible. Provision is made for the removal of the prism-carrier C from its bearing in the frame F at any time for cleaning, and its replacement, without of course disturbing the attachments of the prisms to these pieces. In fact the whole instrument can be taken to pieces in a few seconds (if, say, it has been under water), and half a minute will suffice to clean the faces of the prisms, so that within less than a minute the instrument can be taken to pieces, cleaned, and put together again without the remotest possibility of anything being put out of adjustment. It will therefore be seen that the instrument is incapable of suffering any optical derangement from accident or use.

Even though either of the prisms be cracked, the angles they set out will not be altered, though possibly vision may be impaired. Any wearing of the bearing of C in F can only affect the reading by moving the index upon the scale by an amount equal to the slackness, but no appreciable error could arise from this cause by any wear that could take place after years of use. No doubt the instrument can be destroyed; but so long as an observation can be taken with it, it will be correct if the instrument was

FIG. 11.



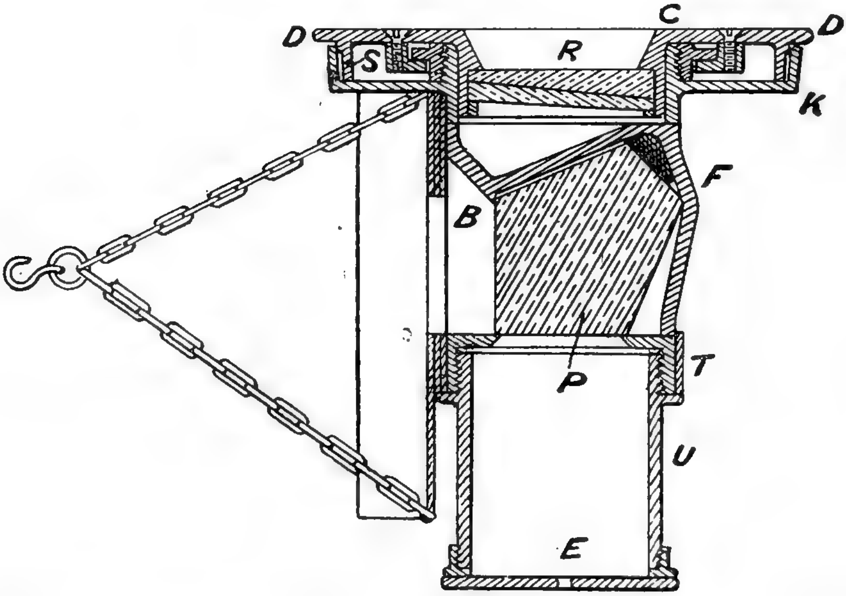
originally correctly made and adjusted. In short, in a well-made instrument there can be no instrumental errors at any time which are not utterly negligible for military purposes, no matter how rough the treatment to which the instrument is subjected.

The cap in which the eye-hole E is formed (fig. 12) is pivoted to the tube U in the manner common with telescope caps. When greater delicacy of observation is wanted than can be obtained by the naked eye, the cap is swung out of the way, and a small Galilean telescope (an opera-glass combination), supplied with the instrument, is inserted into the tube U. The telescope may have a magnifying power of, say, $2\frac{1}{2}$ diameters, and requires no focussing arrangement, as it will necessarily only be used by approximately normally-sighted persons in military range-finding.

The assistant observer's instrument is of the same construction as the chief observer's instrument, except that it is turned right for left, and the prism R is fixed into a carrier which is incapable of rotation in the frame F, and of course the scale is omitted. The refracting prism is in this case only used in the original adjustment of the instrument by the maker.

The second of the three range-finders is unique in having no moving parts of any kind and still working from a constant base. It consists of two fixed-angle instruments (not necessarily setting out exactly right angles), similar to the assistant observer's instrument above described, one right and one left hand. The instrument carried by the chief

FIG. 12.



observer bears a mark M as above described; while the assistant observer's instrument is attached to a board, say, about 15 inches long and 4 inches broad, which may be constructed of several pieces hinged together so as to be readily packed into a small space. Upon the board a scale of reciprocals is painted (fig. 14), the graduations and figures being in white upon a black background, and sufficiently bold to be very readily readable by the chief observer from the other end of the base (20 yards of cord) with the aid of his telescope. The method of using the instrument is illustrated in fig. 13, where A is the assistant observer's instrument attached to the scale S, and B is the chief observer's instrument. The assistant observer adjusts his position, as before, till he sees the mark on the chief observer's instrument reflected upon the distant object. The chief observer then sees the scale projected by reflection upon the distant object at the graduation corresponding to its distance, so that the distant object itself forms an index or pointer for the scale. The scale can be arranged to rest comfortably upon the assistant observer's shoulder when the instrument is placed to his eye. The whole essential adjustment of this instrument, should the angles set out by the instruments be different from those aimed at, may be made by moving the assistant observer's instrument along the scale. Fasteners can then be arranged which cannot hold it in a wrong place at any subsequent time. It will be at once seen that the scale will not require to be at all a nice piece of workmanship. Errors which would be quite inadmissible in an ordinary folding two-foot rule would be inappreciable in this scale. It will be evident, also, that observations can be made by means of this instrument with very great rapidity, and that, as any movement of *either* observer will cause a slight apparent motion of the object relatively to the scale, a mean value can be taken, thus ensuring considerable accuracy. It would require considerable telescopic power to enable the range to be read to one or two

FIG. 13.

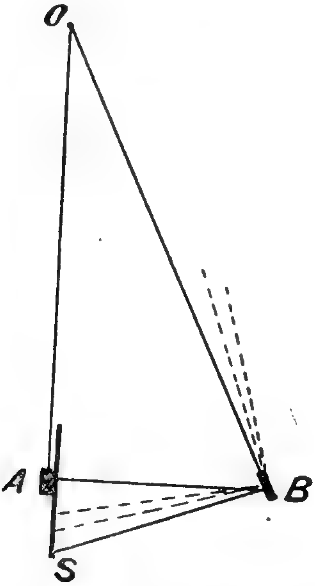


FIG. 14.

yards at 1,000 yards, but the instrument will give indications much within the requirements of the infantry service with great rapidity, while the instrument is quite incapable of derangement.

Although this instrument is not quite so good as the preceding one for the most accurate observations possible on a fixed object, yet for military purposes, where the objects to be fired at are in motion to or from the observers, it becomes just as accurate as the instrument first described when, as would ordinarily be the case, the guns are sighted for a particular range, say 1,000 yards, and the order to fire is given when the enemy has reached this range as indicated by the particular object in the enemy's ranks agreed upon by the two observers coinciding with the 1,000-yard mark as seen by the chief observer.

The third of the range-finders now to be referred to is a modification of the last one. The instruments carried by both observers again set out constant angles. The assistant observer's instrument in this case carries a mark, while the chief observer's instrument is attached to a scale (a reciprocal scale as before), which, however, in this case is narrow, and graduated for reading only from close quarters. Fig. 15 shows the arrangement, A being the assistant observer's instrument, bearing a mark

M, and B the chief observer's instrument. The scale S, attached to B, slides relatively to a mark M_1, which may be supported upon a rifle or light staff or simply held in the hand. The assistant observer adjusts his position with reference to this mark and the distant object, while the chief observer moves his instrument and scale forwards or backwards till he sees the assistant observer's mark in contact with the distant object. He then reads his scale by reference to an index attached to the piece M_1. This instrument may also be adjusted once for all, and so constructed as to be incapable of being put out of adjustment.

FIG. 15.

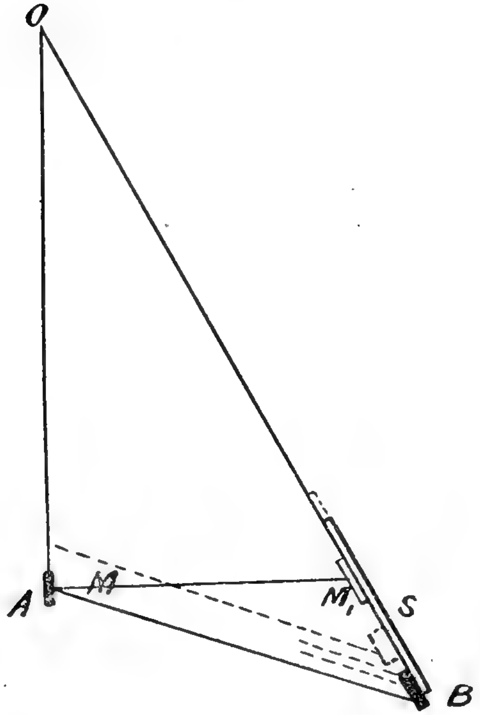
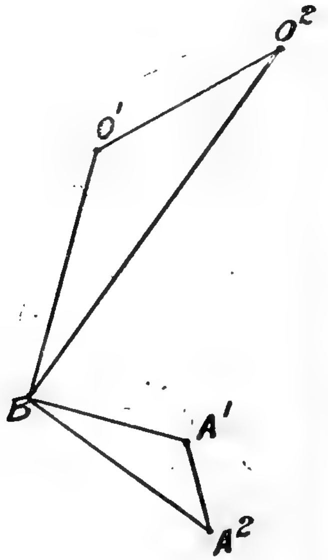


FIG. 16.



The distance between two distant and inaccessible objects can readily be determined by any of these telemeters, but most conveniently perhaps by the first one. For this purpose the scale is set to read any convenient multiple of the base, the base-cord is discarded, and the telemeter used as a fixed-angle telemeter in a manner similar to that described with reference to fig. 2. For example, let the scale for 25 yards base be set to read 1,000 yards, giving a multiplier of 40. One of the observers takes up a fixed position B, fig. 16, and sights one of the distant objects O^1. The other observer moves out in the direction $B A^1$ set out by B's instrument (guided by directions of 'forward' or 'back' from B) till he sees B's mark reflected upon the object O^1, while B sees A's mark also reflected on O^1. The distance $B A^1$ will then be $\frac{1}{40}$ of $B O^1$. The observer A leaves a mark at A^1, and then proceeds in like manner to find the point A^2 corresponding to O^2, B remaining at the same point. Then $B A^2$ will be $\frac{1}{40}$ of $B O^2$, and, since the angle $A^1 B A^2$ will evidently be equal to $O^1 B O^2$, the distance $A^1 A^2$ will be $\frac{1}{40}$ of the distance $O^1 O^2$ between the two distant objects; in fact, the triangle $A^1 B A^2$ will be a map of the triangle

$o^1 B o^2$ on a scale of $\frac{1}{40}$ of the actual size. In this way two observers occupying only a very limited piece of ground may very rapidly determine the data necessary for making a map of the whole tract of country visible from their station.

The value of this method in military operations will be obvious. When troops are about to take up a new position, they may determine beforehand the distances of different landmarks from their intended position, so that the range of the enemy during action may be judged by reference to the points determined. This method of surveying would also, no doubt, prove very useful in exploring and prospecting, since the necessary instruments are very small and not liable to derangement, and in the ordinary practice of engineering surveying there are many cases in which it will be of value in enabling a survey to be made without traversing the ground to be surveyed.

Of course a survey may be made in a similar manner by means of the fixed-angle telemeters referred to above, but the variable-angle instrument has the great advantage, even for this purpose, that the scale upon which the miniatures of the distances to be determined are set out can be varied at will to suit the nature and extent of the ground available for the observers. Besides this, the variable-angle instruments are much better suited, as has been said, for the rapid and accurate determination of direct distances.

It is impossible to state what accuracy is attainable with these instruments, because that will obviously depend upon the nature of the object observed upon, the character of the light at the time of observation, the perfection or imperfection of the eyesight of the observers, the steadiness of the observers, and other elements; but we may say that it is easy to construct the instruments once for all to have in themselves no error that could be visible under the most favourable circumstances in the field, and this condition will be permanent. We have devised special means for measuring (in the workshop) the angles of reflection of the reflecting prisms and the angles of refraction of the refracting prisms to any desired degree of accuracy (to a few seconds of angle), and of adjusting the instruments to give true readings without any field trials. These appliances we hope on a future occasion to bring before the Association.

Roughly speaking, it is easy to determine rapidly the distance of tolerably well-defined objects by means of the first or third instrument described to 10 yards at 1,000, which is, of course, well within any requirements for military purposes; while for surveying purposes, with a little more time and care, and by taking the mean of several observations, a distance of about 1,000 yards can be determined within two or three yards with certainty, and a distance of 500 yards could be determined to one yard. As we have explained, the second instrument described (fig. 13) is not designed for the determination of distances with minute accuracy, but it may be used very rapidly, and gives very reliable results well within the allowable limits for infantry purposes. The instruments are so simple in operation that we have found that a few minutes' practice will enable an observer—previously ignorant of range-finding—to take quite good observations.

In conclusion we would point out that the vital requisites of a military range-finder are that it should be incapable of derangement however rough the treatment, and at the same time that it should possess the facility of operation characteristic of constant-base instruments. Instruments have been devised by military men and others to satisfy either the one or the other of these requirements, but we believe the instruments just described to be the first that have been designed to satisfy both requirements.

Second Report of the Committee, consisting of Sir J. N. DOUGLASS, Professor W. C. UNWIN, Professor OSBORNE REYNOLDS, and Messrs. W. TOPLEY, E. LEADER WILLIAMS, W. SHELFORD, G. F. DEACON, A. R. HUNT, W. H. WHEELER, *and* W. ANDERSON, *appointed to investigate the Action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models.*

[PLATES I–XVIII.]

THE Committee held a meeting in the City and Guilds of London Institute and considered the results obtained since the last report and the proposals of Professor Reynolds for the continuation of the investigation, which were approved.

At a second meeting, held at the Owens College, Manchester, it was arranged that Professor Reynolds should draw up a report on the results obtained.

At a third meeting, held in the committee room, Section G, at Leeds, the report submitted by Professor Reynolds was considered and adopted.

On Model Estuaries.

By Professor OSBORNE REYNOLDS, *F.R.S., M.Inst.C.E.*

CONTENTS.

§ I.—INTRODUCTION.

1. In accordance with the suggestion in the report read at the Newcastle-upon-Tyne meeting of the British Association, 1889, the investigation has been continued with a view (1) to complete the first series of experiments by determining the smallest vertical exaggeration at which similar results can be obtained with tides ranging upwards from half an inch in rectangular estuaries, and so to determine the law of the limits; (2) to determine how far similar effects can be obtained with land water acting on such slopes as had been already obtained in rectangular estuaries; and (3) to investigate the character and similarity of the results which may be obtained with V-shaped estuaries.

2. The two models, subject to such modifications as were required for the various experiments, have been continuously occupied in this investigation, running, driven by the water motor, at all times when they were not stopped for surveying or arranging a fresh experiment. They have thus run about five-sixths of the time day and night. In this way the large model has worked through in the twelve months 500,000 tides, corresponding to 700 years. These tides have been distributed over ten experiments or numbers from 32,000 to 100,000. The smaller model has run more tides than the larger, and these have been distributed over fourteen experiments.

3. The experiments have all been conducted on the same system as is described in last year's report.

Initially, with two exceptions, the sand has been laid with its surface as nearly as possible horizontal at the level of half-tide, extending from the head of the estuary to Section 18, and in the later experiments to Section 17. The vertical sand gauges, distributed along the middle line of the estuary, have been read and recorded once a day. Contour surveys have been made after the first 16,000 tides, and again after the first 32,000, and in the longer experiment further surveys have been made; in all, fifty complete surveys have been made, and forty-four plans, showing contours at vertical intervals corresponding to 6 feet on a 30-foot tide, are given in this report.

The general conditions of each experiment, together with the general results obtained, are given in Table I., pp. 532, 533, and a description of each experiment is given in § III.

The importance of a better means of recording the tide curves was mentioned in last year's report. Such means have been (see p. 522) obtained during this year, and automatic tide curves have been taken as nearly as practical at corresponding numbers of tides during the experiments, these curves being taken at several definite sections in each tank. Two series of these curves have been taken in the later experiments, one in which the paper is moved by a clock, the pencil being moved by a float; the other in which the paper is moved by the tide generator, by which means exactly similar motion for the paper is secured at all points of the estuary, so that differences in the phases of the tide at different parts of the estuary are brought out. These curves are shown on the plates.

Mr. H. Bamford has continued to conduct the experiments, but on account of the very great amount of detailed work the entire time of a second assistant has been occupied. For this the services of Mr. J. Heathcott, B.Sc., were obtained from October to February, when Mr. Heathcott obtained an appointment in the office of the engineer to the L. & N. W. R. in Manchester. Mr. Greenshields then applied for and obtained the post, and has continued the work with great patience and zeal.

§ II.—General Results and Conclusions.

4. *The Limits to Similarity in Rectangular Estuaries.*—In the experiments of last year it was found (1) that as regards

1. Rate of action as measured by the number of tides run;
2. Manner of action; and
3. The final condition of equilibrium

with tides of 0·176 foot and periods of 50 and 35 seconds the results were similar, according to the hydrokinetic law $\frac{p\sqrt{h}}{L}$ constant; (2) that, as regards rate and manner of action, the results obtained with tides of 0·094 foot and periods 23·7 seconds were similar to those with the tide of 0·176; but the experiment had not proceeded to the final condition of equilibrium.

It was also found that with tides of ·088 foot and periods 35·4 seconds the results obtained differed in a marked manner from the others as regards rate and manner of action, so much so as to render the attainment of a final state of equilibrium impracticable.

These results seemed to indicate that for each rise of tide there exists some critical period such that for all smaller periods the results would be similar according to the simple hydrokinetic law, while for larger periods the results would be dissimilar in a greater or less degree to those obtained with periods smaller than the critical period. Whether or not the results obtained with periods greater than the critical periods would present a general similarity amongst themselves, or even similarity under particular relations among the conditions, were still open questions.

The experiments, as shown in Table I., Table II., made this year emphatically confirm the conclusions (1) as to the existence for each rise of tide of a critical period at which the rate and manner of action begin to change, being similar for all smaller periods; (2) these experiments also confirm the general similarity of the final states of equilibrium as regards slopes for periods smaller than the critical period, as shown in Table II.

The experiments (Experiments IV. and VIII., B) this year also show that with tides 0·094 and 0·097 foot the periods 34·4 and 35·4 seconds are greater than the critical periods, although the results show a nearer approach to similarity as regards manner and rate of action than the results obtained last year in II., B, with the tide ·088 foot and period 35·4 seconds, while the final conditions of similarity were approximately reached.

With tides 0·088 foot and periods 69·3 seconds the results in rate and manner of action are emphatically different from those with less than the critical period, and with tides of 0·042 foot and periods 50·5 seconds still greater differences are presented.

On the other hand, it is found with (V., B) tides 0·042 foot and periods 50·5 seconds that if the sand be given a condition corresponding with the condition of final equilibrium, as if the period were above the critical period according to the simple hydrokinetic law, this is a state of equilibrium; and, further, that it is not a state of *indifference* is shown, since on diminishing the period the sand readily shifted so as to bring it nearer the theoretical slope for the new period. This shows that the state of equilibrium follows the simple hydrokinetic law for periods greater as well as less than the critical period, which is thus shown to be critical only as regards rate and manner of action in reducing the sand from the initial level state to the final condition.

The experiments carefully considered suggest that there is some relation between the rise of tide and critical period. They do not, however, cover sufficient range to indicate what this relation is with any exactness. The critical period diminishes with the rise of tide, but much faster than the simple ratio.

5. *Causes of the Change in Manner and Rate of Action.*—The change in the action which sets in at the critical period is the result of some action, of which no account is taken in the simple hydrokinetic law. A list of five such sources of possible divergence from the hydrokinetic law is included in last year's report (p. 339), and with a view to obtain an indication of some relation between the rise of tide and period (or vertical exaggeration, as compared with the standard tide of 30 feet, by the kinetic law), which relation would be a *criterion* of the limiting conditions under which the simple kinetic law may be taken as approximately accurate, these five discarded actions were carefully considered.

The fouling of the sand by the water, although it comes in as preventing further action, cannot take any part in imposing these limits, since it is at the immediate starting of the experiments that the action is observed to fail. For the same reason the limits cannot be in any way due to the *drainage from the banks*, as these banks have not appeared above water.

Again the limit cannot be due to the *size of the grains of sand* because it would then occur at particular velocities, whereas this is not the case.

The other actions are the *bottom resistances* and the *viscosity of the water, which causes a definite change*[1] *in the internal motion of the water as the velocity falls below a point which is inversely proportional to the dimensions of the channel.*

That this last source of divergence from the simple kinetic law must make itself felt at some stage appeared to be certain. But the critical velocity at which the motion of the water changes from the '*sinuous*' or *eddying* to the *direct* is inversely proportional to the depth, and by the kinetic law the homologous velocities in these experiments are proportional to the square roots of the depths only; hence this action would seem to place a limit, if it were a limit, to the least tide at which the kinetic law would hold independently of the period, and this is not the case. Observation of the action of the water above and below the critical periods, however, confirmed the view that the limit was in some way determined by this critical condition of the water. For when water is running in an open channel above the critical velocity the eddies of which it is full create distortions in the evenness of the surface which distort the reflections, creating what is called swirl in the appearance of the surface. Now it was noticed and confirmed by careful observation that in the cases where similarity failed the swirl was absent at the commencement of the experiment, while it was easily apparent, particularly on the ebb in the other experiments. Subsequently it appeared that the velocity of the water, particularly during the latter part of the ebb, which has great effect in the early stages, might be much affected by the bottom resistances, and hence not follow exactly the kinetic law.

6. *Theoretical Criterion of Similar Action.*—The velocities of the water running uniformly in an open channel, i being the slope of the surface and m the hydraulic mean depth, is given by

$$v = A\sqrt{im},$$

where A is constant.

If, then, i is proportional to e (the exaggeration of scale) and m proportional to h, since at the critical velocity v is inversely proportional to h, at this velocity $h^3 e$ has a constant value.

The function $h^3 e = C$ is thus a criterion of the conditions under which similarity in the rate and manner of action of the water on the sand ceases.

7. *The Critical Values of the Criterion for Rectangular Tanks.*—Taking h to represent the rise of tide in feet, and e to be the vertical exaggeration as compared with a 30-foot natural tide by the simple hydrokinetic law, the values of this criterion have been calculated for each of the experiments and are given in Table I.

Experiments I. and II., B, First Report, C=0·046, showed marked sluggishness and local action; IV., B, C=0·058 and VIII., B, C=0·064, showed less, but still a certain amount of sluggishness and local action,[2] while in III., B, C=0·083, the rate of action was good and the action similar to the experiments with values for C higher than 0·087,[2] whence it would seem that the critical value of the criterion is about 0·087, and it may provisionally be assumed that C=0·09 indicated the limits of the conditions of similar action.[2]

[1] Reynolds on the Two Manners of Motion of Water, *Phil. Trans.* 1883, pt. iii.

[2] In both these experiments, IV. and VIII., B, the mean level of the tide was above the initial level of the sand, which would naturally increase the value of the criterion.

8. *The Value of the Criterion for V-shaped Estuaries.*—This critical value of C deduced from the experiments in rectangular tanks appears to correspond very well with the results of the experiments in the V-shaped estuaries. In the experiments Table I. with V-shaped estuaries in the small tank, the value of C is in no case far from the critical value ·09 on either side. In Experiment IX., B, however, the value of C at starting was only 0·046 as in I., B, and in consequence of the observed sluggishness and local character of the action in the lower estuary, the rise of tide was increased from 0·088 to 0·11, which remedied the action and raised the criterion to 0·101, and in Experiments X. and XII., B, and in I., D, the values are between 0·095 and 0·084. In Experiments II., D, F, and F′, owing to the falling off in the tide in consequence of the addition of the river, the criterion is as low as 0·073. In these experiments signs of sluggishness and local action in the lower estuary were observed at starting, and the difference in the action of the upper estuary as compared with Tank E in respect of closing up the tidal river may have been due to the low value of the criterion.

In the experiments in the large tanks the values of C are all well above the critical value: the nearest are the experiments in Tank E, C=0·17, which is only double the critical value, and the action was as quick and general as in the case where C=0·5.

It may be noticed that the range through which the value of C as a criterion has been tested is small. Had the form of criterion been apprehended sooner this might have been somewhat extended, though considerable adaptation of the apparatus would be required to carry it far.

9. If C=0·08

With a tide	0·1 ft.	the greatest period is		32 secs.	and least exaggeration		80.
”	0·12 ft.	”	”	60 secs.	”	”	47.
”	0·14 ft.	”	”	102 secs.	”	”	30.
”	0·2 ft.	”	”	6 mins. 9 secs.	”	”	10.
”	0·43 ft.	”	”	1 h. 33 m. 48 s.	”	”	1.

From which the size of tanks and length of periods necessary to verify this law for exaggerations of less than thirty can be seen.

10. *The General Distribution of Sand in V-shaped Estuaries.*—The experiments all show that with sufficiently high values of the criterion, as in the rectangular tanks so in those of symmetrical V-shape, the sand arrives at a definite general state of equilibrium after a definite number of tides. This state in the rectangular tanks was a general slope which corresponded to a definite curve, twelve miles long as reduced by the kinetic law to a 30-foot tide, between the contours at high and low water in the generator. This slope was furrowed by 3 or 4 shallow channels at distances of some two miles, commencing very gradually at the top and dying out at some distance below low water. In the V-shaped estuaries the state of equilibrium differs from that in the rectangular tanks in a very systematic manner; it consists in a main low-water channel commencing at the end and extending all the way down the V out into the parallel portion of the tank. If this channel is in the middle it is the only channel, but if, as is as often as not the case, it takes one side of the estuary, then at the lower end there is on the other side a second channel starting at some distance down the estuary. The height of the banks above the bottom of the main low-water channel towards the lower end of the V is much greater than in the rectangular estuaries. No general method of comparing the general slope or distribution of the sand in the

V-shaped estuaries has been suggested other than that of comparing the contoured plans and the longitudinal section taken down the highest banks and lowest channels, together with the cross sections which have been plotted on the plans. These are very similar for the similar tanks and corresponding periods. They show that the slope in the channels down to low water is nearly the same as in the rectangular tanks, the level of low water being reached at distances from the head of the estuary a little greater than in the rectangular tank, and a little greater in the long V than in the short. Below low water the slope in the channels is less than in the rectangular estuaries, which is, doubtless, a consequence of lateral spreading. The slope of the banks is much less than in the rectangular tanks, and these extend from two to three times as far from the top of the estuary according to the angle of the V.

The range of observations on V-shaped estuaries has necessarily been limited, and time has not sufficed to duly consider all the results obtained, but the following conclusions may be drawn :—

(1) In similar shaped V-estuaries configurations similar according to the simple hydrokinetic law are obtained irrespective of scale, provided the criterion of similarity has a value greater than its critical value. (2) That the general character is that of a main channel and high banks. (3) That the estuaries are longer in a degree depending on the fineness of the V than rectangular estuaries with corresponding tides, while the low-water contour reaches to nearly the same distance from the top of the estuary.

11. *In the experiments with a long (fifty miles) tidal river increasing in width downwards slowly until it discharges into the top of the V-shaped estuary* the character of the estuary is entirely changed. The time occupied by the tide getting up the river and returning causes this water to run down the estuary while the tide is low, and necessitates a certain depth of water at low water, which causes the channel to be much deeper at the head of the estuary. In its effect on the lower estuary the experiments with the tidal river are decisive, but as regards the action of silting up the river further investigation is required, both to establish the similarity in the models and to ascertain the ultimate state of equilibrium.

It may, however, be noticed that the general conditions of the experiments in Tank E do not differ greatly from the conditions of some actual estuary, as, for instance, the Seine. This estuary is some thirty miles long before it contracts to a tidal river which extended fifty miles further up. In the model the tidal river reduced to a 30-foot tide is forty-nine miles long and the V extends down twenty-eight miles further, while the results in the model show about the same depth of water in the channel down the estuary as existed in the Seine before the training walls were put in.

12. *The Effects of Land Water.*—These come out clearly in the experiments, which show that the stream of land water running down the sand, although always carrying sand down, does not tend to deepen its channel, since at every point it brings as much sand as it carries away. If it comes into the estuary pure, it carries sand from the point of its introduction and deposits it when it gets to deep water, somewhat deepening the estuary at the top and raising it below, which effect is limited by the influence the diminished slope has to cause the flood to bring up more sand than the ebb carries down. The principal effect of the land water is that running in narrow channels at low water, which

are continually cutting on their concave sides, it keeps cutting down the banks, preventing the occurrence of hard high banks and fixed channels. When the quantities of land water are small as compared with the tidal capacity of the tank, its direct action on the *régime* of the estuary is small. But that it may have an indirect action of great importance in connection with a tidal river is clearly shown. In the upper and contracted end of a tidal river the land water may well be sufficient to keep it open to the tide, whereas otherwise it would silt up. This was clearly the effect in the experiments E, 1 and 2, and by keeping the narrow river open the full tidal effect of this was secured on the sand at the top of the estuary, causing a great increase of depth. The effects of large quantities of land water, such as occur in floods, have not yet been investigated.

13. *Deposit of the Land Water in the Tidal River.*—One incident connected with the land water in the tidal river is worth recording, although not directly connected with the purpose of the investigation.

The land water, one quart a minute, was brought from the town's mains in lead pipes. It is very soft, bright water, and was introduced at the top of the estuary. This went on for about three weeks. At the commencement the sand was all pure white, and remained so throughout the experiment except in the tidal river. At the top of the river a dark deposit, which washes backwards and forwards with the tide, began to show itself after commencing the experiment, gradually increasing in quantity and extending in distance. At the end of the experiment the sand was quite invisible from a black deposit at the head of the river and for 5 or 6 feet down; this, then, gradually shaded off to a distance of 12 feet. Nor was it only a deposit, for the water was turbid at the top of the river and gradually purified downwards.

On the other hand, in the precisely similar experiment, without land water the sand remained white and the water clear right up to the top of the river. This seems to suggest that these experiments might be useful to those interested in river pollution.

14. *The International Congress on Inland Navigation.*—During the Fourth International Congress on Inland Navigation, held in Manchester at the end of July, the members were invited to see the experiments then in progress, the subject being one which was occupying the attention of the Congress. Advantage of the invitation was taken by many engineers, and especially by the French engineers. M. Mengin, engineer in chief for the Seine, stated in a paper [1] read at the Congress that in consequence of the paper (read by the author before Section G at Manchester) the engineers interested had advised the Government to stop the improvement works on the Seine until a model having a horizontal scale of 1 in 3,000 was constructed, and the effect of the various improvements proposed investigated in the model, the model being then nearly ready, but the experiments had not commenced. M. Mengin paid several visits to the laboratory and carefully examined the apparatus and experiments, for which all facilities were placed at his disposal.

15. *Recommendations for further Experiments.*—Although the immediate objects proposed for investigation this year have been fairly accomplished, there remain several general points on which further information is very important, besides the further verification of the criterion of similarity, and the determination of the final conditions of equilibrium with tidal rivers, already mentioned. It seems very desirable to determine the

[1] International Congress on Inland Navigation, 1890.

effect of tides in the generators diverging from the simple harmonic tides so far used, simple harmonic tides being the exception at the mouths of actual estuaries. It would also be desirable before concluding these experiments that they should include the comparative effects of tides varying from spring to neap.

§ III.—Modifications of the Apparatus.

16. *General Working of the Apparatus.*—The apparatus has worked perfectly in all respects except that of the driving cord connecting the water motor with the gearing. For this cord hemp was first used, as it was liable to be wet. This hemp cord wore out with inconvenient rapidity. A continuous cord made of soft indiarubber was then tried, and, after several attempts, has been made to answer well. The only other failure was the small pinion, which was fairly worn out, and had to be replaced.

17. *Extensions.*—For carrying out the experiments on the V-shaped estuaries the original tanks had to be increased in length. To do this it was necessary to remove temporarily part of the glass partition dividing the engine room of the laboratory, in which the tanks are placed from the testing room. This being done, the tanks were then extended, as shown in Plate I., the first extension being an addition of a trough 6 feet long and 2 feet wide to Tank A, and a similar extension of half the size to Tank B, the new tanks being thence called C and D.

18. *Extensions for Tidal Rivers.*—The second extension consisted of a trough 19 feet long and a foot wide to the end of C, the new tank being thence called E. The corresponding extension to D was not at first made in the same way, because to do so would require the removal not only of a panel of the glass partition, but also of a fixed bench, which was a much more serious matter, or else the extension would have closed up an important passage. The extension was therefore made, as shown in Plate XVII., which admitted of the tidal river being the corresponding length to that in E, but required a bend of 180°, which was effected by two sharp corners. This tank was thence called F′. This was the best that could be done during the time the students were in the laboratory. It was not certain that the corners would produce any sensible effect, whereas if the results obtained in F′ were not similar to those in E no time would have been lost, since the straight extension could not be made till the end of June. As the results in F′ were not similar to those in E in a way which might be explained by the bends, as soon as possible the straight extension was made similar to E, and the tank called F.

All these tanks were constructed in the same manner as the original tanks, and covered with glass at the same level as A and B, under which glass survey lines, conforming to those on A and B, were set out.

19. *The Numbering of the Cross Section.*—The extension of the tanks raised the question as to how the new cross sections should be numbered: the numbering of A and B ran from the ends of the tanks, and it seemed best to run the numbers in C and D from the ends of these tanks, continuing this new numbering to the generators. On the other hand, as the long, narrow extensions in E and F were more in the nature of a tidal river than an estuary, the numbers in these were carried backwards 1, &c., from the ends of C and D, in which the cross sections preserved the same numbers as before.

20. *Appliances for Land Water.*—The introduction of land water, besides the extension of the pipes for its introduction, required certain arrangements for its regular supply in definite quantities. The water was to be taken from the town's mains. And in the first laying down the pipes it had been anticipated that it would be sufficient to regulate the supply by cocks against the pressure in the mains. Fresh water regulated in this way had been from the first supplied in small quantities into the generators to ensure the level being kept properly. The experience thus gained showed that it was impossible to obtain even approximate regularity in this way, as the nearly closed cocks always got choked even within twenty-four hours.

To meet this it was arranged to supply the water through thin-lipped circular orifices under a small but constant head of water, which head can be regulated to the quantity required. The head of water in the tank from which the orifices discharge is regulated by a ball cock, which only differs from an ordinary ball cock in that the ball is not fastened directly on to the arm of the cock, but is suspended from it by a rod so arranged that the distance of the ball below the arm can be adjusted at pleasure. This arrangement has answered well. The cylinder in which the ball cock works is made of sheet copper, with a water gauge in the form of a vertical glass tube, with a scale behind to show the height of water above the orifices, which are made in the bottoms of two lateral projections from the sides of the cylinder. One of these orifices feeds the large and the other the small tank. The streams from the orifices descend freely in the air for about 4 inches, and are then caught in funnels on the tops of lead pipes leading to the respective tanks. The cylinder is fixed against a wall about 8 feet above the floor, and conveniently near the tanks. Any obstruction in the pipes conveying the water to the tanks would be at once shown by the overflow of the funnel. The orifices are made with areas in proportion to the quantities to be supplied to their respective tanks. Then the supply cock connecting the ball cock with the main is fully opened, and the ball is adjusted till the quantity supplied to one of the tanks is correct. The other is then measured; if this is not found correct one of the holes is slightly enlarged until the proportions are correct.

This having once been done for an experiment, no further regulation is required except to test the quantities and wipe the edges of the orifice. When the tanks are stopped for surveying, the water is shut off from the main and simply turned on again on restarting.

21. *The Tide Gauges.*—In the experiments made last year a tide gauge was used. This gauge consisted of a small tin saucer with a central depression in its bottom, in which a vertical wire rested, restraining any lateral motion in the float, the wire being guided vertically by a frame made to stand on the level surface of the class covers, while the wire passed down between two of the covers opened for the purpose, the frame carrying a vertical scale. This gauge was used both to adjust the levels of the water and to obtain tide curves by observing the heights of the tide at definite times and then plotting the curves with the heights of the tide as ordinates and the times as abscissæ.

For the earlier experiments this year the same gauge was used for both purposes, and it has been used all through for the purpose of adjusting the levels of the water, automatic arrangements being used for drawing the tide curves.

In devising these automatic arrangements several difficulties presented themselves besides those inherent in all chronographic apparatus. Anything in the nature of standing apparatus was inadmissible, as it would interfere with the working and adjusting of the tanks. The apparatus must be such as could be put up and taken down with facility, and hence could not admit of complicated arrangements. A pencil worked direct by a float with a drum turning about a vertical axis by a clock, all to stand on the level glass surface, appeared the most desirable arrangement. In the first instance, a clock driving a detached vertical cylinder with a cord was kindly lent by Dr. Stirling from the Physiological Laboratory of Owens College, and an arrangement of float and stand was constructed by Mr. Bamford. The loan of this clock was temporary, and experience gained with it led to the purchase of an ordinary Morse clock from Latimer, Clark, & Co. at comparatively small cost. A pulley was fitted so that the clock would drive the borrowed cylinder. This clock did its work quite as well as the more costly instrument. Its rate of action varied considerably with the resistance of the apparatus to be driven, so much so that the curves taken at different times from the same experiment could not be compared by superposition. Still, the action of the clock during the individual observations was sufficiently regular to give a fairly true tide curve, and it became obvious that it would be impossible to obtain any independent clock-driven apparatus that would give absolutely constant speeds such as would admit of the comparison of the curves taken from different parts of the estuary by direct superposition. To obtain such comparison it would be necessary to move the paper by the gearing which moved the generator.

22. *Compound Harmonic Tide Curves.*—On considering how best this might be done, it appeared that if the paper had a horizontal motion corresponding to the rise and fall of the generator while the pencil had a vertical motion corresponding to the rise and fall of the tide at any point in the tank, then if the tide were in the same phase as the generator the curve would be a straight line or an ellipse of infinite eccentricity with a slope ($\tan \theta$) equal to the rise of tide divided by the horizontal motion imparted to the paper, while any deviation of phase would be shown by the character of the ellipse or closed curve described by the pencil, and that to obtain the *time-tidal* curve from such curves would be easy by projecting on to a circle, while for the purpose of comparison and bringing out any difference of phase or deviation from the harmonic curves such compound harmonic curves would be much more definite than the harmonic curves. This plan was therefore adopted with the happiest results, for, although it may take some study to become familiar with the curves, the obvious differences in these curves taken at different parts of the tanks and at the same part at different stages of the progress towards a state of equilibrium, together with the similarity of the curves taken in the two tanks or in different experiments at the corresponding places and corresponding numbers of tides run, including the final states of equilibrium. Plate XVIII. brings out more emphatically than anything the interdependence of the character of the tide on the arrangement of the sand and the coincidence of a state of equilibrium of the sand with a particular tide curve at each part of the estuary.

In these experiments the balance of the tanks has been adjusted so as to make the time intervals of rise and fall of the generator equal, *i.e.*, to make the motion of the generator harmonic, so that these compound harmonic curves are at all parts of the tank comparable with a simple harmonic motion. But it is important to notice that they are not essentially so, being merely comparable with the motion of the generator, so that if the generator were given a compound harmonic motion, such as that of the tide in the mouths of most estuaries, these curves would have a different dynamic significance. These curves would still be valuable as showing the state of progress and final similarity of the tidal motion at the same parts of the estuaries, but to bring out their dynamical significance it would be necessary to substitute a simple harmonic motion with the same period for that of the generator.

§ IV.—Description of the Experiments on the Movement of Sand in a Tideway from September 9, 1889, to September 1, 1890.[1]

23. *Continuation of Experiments VII., Tank A, and III., B, Plate III., September 7 to October* 11.—These experiments were in progress at the time of the Newcastle Meeting of the British Association, and had so far advanced that tracings of the first surveys were exhibited and included in the First Report. So far as they went, they took an important place in the conclusions arrived at in that report, showing that with a vertical exaggeration of 100 the results obtained in the small tank (B) with rectangular estuaries without land water as to rate and general distribution of the sand were closely similar to those obtained in A, and that the mean slopes reduced to a 30-foot tide in these experiments agreed with those obtained in A, with vertical exaggerations of 64. It was desirable to continue these experiments to see how far a state of equilibrium had been arrived at. This was accomplished by the assistance of Mr. Foster, who kindly looked after the running of the tanks till the return of the author and Mr. Bamford in October, and thus enabled a month which would otherwise have been wasted to be utilised in obtaining an experience of the effect of about 100,000 tides after apparent equilibrium had been obtained in each tank. Daily records of the counters were taken, and although there were several stops the intervals of running gave the periods very constant.

The plans show but little alteration, except that the sand, particularly in B, had shifted upwards and accumulated somewhat at the head of the estuary, leaving the slope the same; a circumstance which would be accounted for by a difference in the level of the water, and which is also indicated by the mean slope reduced to a 30-foot tide shown in Plate II. The agreement of the slopes here shown as compared with the mean slope in the case of Experiment V., A, which has been introduced in this diagram for the sake of comparison, is quite as great as could be expected, considering the difficulties of the experiments, and affords very valuable evidence of the permanence of these slopes when once a condition of equilibrium has been attained.

In respect of the ripple the two tanks presented a very different appearance, which is clearly shown in the plans and sections. While the ripple in A was comparatively small and shallow, in B it was larger and deeper than anything previously noticed; that this was a symptom of the condition of B being on the verge of dissimilarity seemed probable, and to test this the period of B was increased from 23·85 to 26·5 seconds,

[1] In the published report of these experiments it is not thought desirable to give the daily records of progress in the notebook.

and it was allowed to run on 16,000 more tides and again surveyed. Plan 3 shows the result; the ripple has increased in breadth though rather diminished in depth.

24. *Experiments to find the Limits to Similarity. Experiment IV., B, Plate III., October* 22 to *November* 27.—In this the rise of tide was 0·094 foot and the vertical exaggeration as compared with a 30-foot tide 71. In Experiments I. and II., B, with a rise of tide 0·088 and a vertical exaggeration 68, described in the First Report, it had been found that the rate and manner of distribution of the sand did not correspond with that in the corresponding experiment in the larger tank, indicating that with an exaggeration 68 the tide of ·088 was somewhat below the limit of similarity. The determination of these limits being a primary object of the investigation, it appeared desirable to repeat these experiments with a slightly higher tide. In IV., B, the character of the action presented the same peculiarities as previously observed, but in a smaller degree, and the final state, as shown in the plans and in the curve of slopes (Plate II.), is a much nearer approach to the general law, the conclusion being that in IV., B, the conditions were still below the limit, but nearer than in I. and II., B.

Experiment VIII., A, October 22 *to November* 14.—This was an experiment to determine the manner of action with the same horizontal scale as the first part of Experiment V., A, but half the rise of tide. Experiments I. and II., B, with a rise of tide of ·088 foot and a period of 36 seconds, being a vertical exaggeration of 68, had indicated that with this rise of tide a change in the manner of action had already set in, but it was none the less desirable to see what would be the character of the action and the final state of equilibrium well below this limit.

The rise of tide in VIII., A, was 0·088 foot and the mean level 0·138 foot from the bottom, and the period to 70 seconds, the sand being placed level at a uniform depth of $1\frac{1}{2}$ inch to Section 18 as in the previous experiments. The vertical exaggeration would thus be only 34.

The manner of action of the water on the sand was in this case essentially different from that in any previous experiments even in I. and II., B, although it presented characteristics which had been indicated in those experiments. Instead of the sand being in the first instance rippled over the whole surface a middle depression was formed, extending some way up the estuary, the bottom and sides of which were rippled; the rest of the sand soon became set and yellow. After 16,000 tides a survey was made and the experiment continued to 24,000, when another partial survey was made, showing very small alterations, and those nearly confined to the rippled channels. It was, in fact, clear that the apparent equilibrium was owing to the sand having become set, and that to proceed till real equilibrium was established would take an almost indefinite time.

As the setting of the sand, owing to the slow action of the water, appeared to play such an obstructive part, it seemed possible that better results could be obtained if the sand could be kept alive with waves. Accordingly the experiment was stopped, to be repeated with waves.

Experiment IX., Tank A, Plans 1, 2, 3, *Plate IV.* (*with Intermittent Waves*), *November* 16 *to January* 4.—The conditions were the same as in Experiment VIII., with the addition of the waves.

This experiment presented the same characteristics as those observed in VIII., A. The rate of action did not fall off so rapidly or completely as in VIII., but was mainly confined to the channels; and, although the experiment was continued to 57,000 tides, the condition of equilibrium was far from being arrived at owing to the setting of the sand. After the last survey a small stream of land water (one pint per minute) was admitted at the top of the estuary without any perceivable effect for 1,000 tides, whereupon the experiment was stopped.

Experiment V., B, Plan 1, *Plate IV., November* 21 *to December* 2.—This was the corresponding experiment in B to Experiment VIII. in A, the rise of tide being one-half inch (·042 foot), and the period 50 seconds, exaggeration 32. The characteristics were yet more definitely marked, rippling being entirely absent, and the action being entirely confined to the space between Sections 14 and 18.

Experiment VI., B, December 5 *to December* 9.—In this experiment the conditions were exactly the same as in Experiment V., B, except that the sand, instead of being laid level, was laid with a slope of 1 in 124, the slope corresponding to the theoretical condition of equilibrium as in the previous experiment. After 6,757 tides with a mean period of 60·1 seconds the sand was not moved anywhere in the slightest degree.

Experiment VII., B., Plans 1 *and* 2, *Plate V., December* 9 *to January* 3.—This was a continuation of Experiment VI., with the tidal period diminished in the ratio 1 to $\sqrt{2}$ from 50 to 35·35.

The effect of changing the period would be to increase the vertical exaggeration, so that the slope of 1 in 124 would not be the theoretical mean slope of equilibrium as previously determined, which would be 1 in 87, so that any sensitiveness to the condition of equilibrium would be shown by the shifting up of the sand.

This commenced at once and continued until the mean slope was about 1 in 100 above Section 13.

The absolute quiescence of the sand in Experiment VI., B, when laid with the mean slope of equilibrium corresponding to the period, together with the increase of the slope with the increase of period in Experiment VII., B, indicates that, although, as shown in Experiment V., the limiting conditions under which the water could redistribute the sand from the level condition had been long passed, the conditions of equilibrium remained the same; or, in other words, that for a half-inch tide, with a period of 50 seconds—*i.e.*, an exaggeration of 32—with the sand originally distributed, according to the theoretical slope of equilibrium, the sand will be in equilibrium, while if the sand be laid with a smaller slope the water will shift it, tending to institute the slope of equilibrium.

25. *Rectangular Estuaries with Land Water. Experiments X., A, and VIII., B, Plate VI., January* 7 *to March* 10.—The conditions in Tank A were the same as in Experiment V., Plan 1. The sand lay 0·25 foot deep, height of mean tide 0·256, rise 0·176, tidal period 50·2 seconds. A tin saucer was placed on the sand under Section 1 in the middle of the estuary, and a stream of water (one quart per minute, about 1 in 170 the tidal capacity of the estuary per tide) run into the pan.

During the early distribution of the sand the land water produced no apparent effect, but as the sand approached a condition of equilibrium the effect of the fresh water in keeping a channel full of water at low tide from the source all down the estuary was very marked. The effect of this river in distributing the sand at the top of the estuary was also marked. The channel did not remain in one place; it gradually shifted from the middle towards one or other of the sides, cutting away high sandbanks until it followed along the end of the tank into the corner, and then flowed back diagonally into the middle. Then, after some 10,000 tides, a fresh channel would open out suddenly towards the middle of the estuary, and then proceed in the same gradual manner perhaps to the other side. This happened more than once during the progress of the experiment, which was carried to 85,000 tides. The different positions of the channels are apparent in the plans 1, 2, and 3. The comparison of these plans and the accompanying sections with Plan 1, Experiment V., in the last report shows but slight general effect of the land water—so slight, indeed, that it might pass almost unnoticed. This shows that the land water does not alter the greatest height of the banks or the lowest depth of the channels.

It will be noticed, however, in the plans that the land water has lowered the general level of the sand in the middle of the estuary at the top and raised it towards low water. This effect comes out in the mean reduced slopes shown in Plate II. From these it appears that the effect of the land water, by continually ploughing up the banks at the top of the estuary, has been to disturb the previous state of equilibrium, lowering the sand near the top and raising it further down the estuary.

In Experiment VIII., B, the conditions at starting were the same as those in IV., B, and one quart of land water in 2·8 minutes was admitted in the same manner as in X., A, the period being 35·4 seconds. The quantity of land water per tide was one-fourth the quantity in A, while the capacities of the estuaries are as 1 to 8, or the percentage of land water in B was 1·8 that of the tidal capacity at starting. After running 600 tides the rise of tide was increased from 0·094 to 0·097 foot without any alteration in the period. The experiment was then continued to 91,184 tides.

The apparent effects of the land water observed were exactly the same in character as in A, but were decidedly greater on account of the larger quantity. The curves agree fairly with those in A.

26 *Experiments in short V-shaped Estuaries with and without Land Water.*—In the tanks A and B inner vertical partitions were introduced so as to form the upper end of the tank A into a symmetrical V, of length 6 feet and greatest breadth 4 feet; while that of tank B was formed in a similar manner into a V of length 3 feet and breadth 2 feet. The lengths of the tanks were thus unaltered, the tidal capacity being reduced to three-quarters of what it was before.

The sand was arranged in a similar manner to that previously adopted, except that the initial depth of the sand was 4 inches (0·33 foot in A) instead of 3 inches, and the scummers raised so as to maintain the water higher in a corresponding degree.

Experiments XI., A, and X., B, Plate VIII., March 18 *to April* 29.—In Tank A the rise of tide was 176 and the period 47·20. The experiments were first started without land water. The observed character of the action was much the same as with the rectangular estuaries, being more intense towards the top of the V, and quieter at and below the broad end.

The first attempt in Tank B showed that, owing to the diminished capacity of the estuaries, the sand would not come down even so well as in corresponding experiments with rectangular estuaries. This led to the abandonment of Experiment IX., B, and starting X., with a rise of tide

0·110, without, however, altering the level of the sand. The experiments were continued in both tanks without land water until about 40,000 tides had been run, and Plans 1 and 2 had been taken. These plans show the similarity of the effects in the two tanks. They also show decidedly the character of the distribution of the sand in the V-shaped estuary. It will be seen that the extreme positions of the contours up the estuary are much the same as in the rectangular estuaries, while the extreme positions down the estuaries are very much increased. The low-water contours extends from Section 11 to Section 19, while in Experiment V., A, Plan 1, it extend from Section 11 to Section 13. The low-water channels are nearly the same depth at corresponding points all down the estuary in both experiments, while in the V estuaries the banks extend 6 to 7 miles (reduced to a 30-foot tide) further down.

. After Experiment XI., A, and X., B, had proceeded to about 40,000 tides, corresponding quantities of land water were introduced at the tops of the estuaries, one quart in one minute in A, about 1 in 140 the tidal capacity; in B one quart in 5·68 minutes, or about 1 in 140 the tidal capacity. The tanks were then run on for 12,000 tides, and surveys for the plans 3 made. The general effect of this land water, as shown in these experiments, is, as before, to lower the sand at the tops of the estuaries and slightly to raise it at the bottom. They were not, however, continued long enough to show a state of equilibrium. As in the rectangular estuaries, the detailed effects of the land water were much more observable than those shown in the surveys. The land water continually ploughed up the sand at the top of the estuary and kept the banks down, but owing to the narrowness of the estuary the general effects of this were not so striking as in the rectangular estuaries.

Experiments XII., A, and XII., B, with Land Water, Plate X., April 29 *to May* 19.—These were under conditions precisely similar to XI., A, and X., B; XI., B, with land water, was started, but owing to an accident it was re-started as XII., B.

Both experiments were run about 16,000 tides and then surveyed, and then run on about 16,000 more tides and surveyed again.

The plans are all very similar, and show but little difference from the plans 3 with land water in the previous experiments.

27. *Experiments in long V-shaped Estuaries without and with Land Water in Tanks C and D.*—Tank C was formed by extending A by adding a rectangular trough to the top, and so as to admit of partitions forming a V extending from Section 23 (12 A), and D was formed by extending B in a similar manner. The lengths of the tanks were thus extended 6 feet and 3 feet greater than A and B, while the capacities were the same as the original capacity of A and B.

The sand in C (A extended) was laid 4 inches deep from the top of the V to Section 28·5 C (17·5 A).

The sand in D (B extended) was laid $2\frac{1}{4}$ inches deep from the top of the V to Section 28·5 D (17·5 B).

Experiments I., C and D, Plate XI., May 24 *to June* 16, *without Land Water.*—In C the tide was 0·162 foot., and the scummer was placed so that the mean tide when running was 0·008 foot above the initial level of the sand; this was not observed at the time, being a consequence of the land water raising the level of low water by the necessity of getting over the weir.

In D the tide was 0·105 foot and the mean tide was ·010 foot below the initial level of the sand. Thus reduced to a 30-feet tide, the initial depth of the sand was 5 feet higher in C than in B. The experiments were run for about 16,030 tides and surveyed, then re-started, when the level of water in C fell owing to a leak in the scummer.

This lowered the sand at the lower end of the estuary, and a partial survey was made, and then the experiment continued until both tanks had exceeded 30,000 tides. The results, as shown in the plans, are very much alike, considering the very considerable differences in the initial quantities of sand. Owing to the much higher level of the sand in D, the top of the V was much more silted up in the early part of the experiment, and the sandbanks were higher towards the bottom of the estuary. Otherwise both tanks show the same characteristics.

The highest point of the contour low water in the generator is still at Section 15, while the highest point of the contour at high water in the generator is at Section 4, so that the distance between the highest points of these sections was still about 11 miles, while the banks at low water extended down to Section 26.

Experiments II., Tanks C and D, with Land Water, Plate XII., June 17 *to July* 8.—The conditions in these experiments were the same as in Experiments I., Tanks C and D, except that the scummer in D was altered, until the mean tide level was only ·003 foot above the initial height of the sand, and in Tank A ·002 foot above, while the rise of tide in A was slightly greater and that in B slightly less.

Surveys were taken at about 16,000 and 32,000 tides respectively; they are very similar, and the effects of the land water are, as before, to slightly raise the lower sand and lower the upper. At low water there was still water in the channels right up to the top of the estuary, and at high water there was what would correspond in a 30-foot tide with 10 or 12 feet of water at the top in the low-water channels.

28. *Experiments in long V-shaped Estuaries with straight tidal Rivers extending up from the top of the V with and without Water in Tanks E, F′, and F.*—Tank E was formed by opening out the partition boards in Tank C at the end of the V to a distance of 4 inches. That portion of the V below Section 12 remained as in Tank C, the position of the partition boards not being altered. At a section, 12·5, a small angle was formed, so that while the boards above the section remained straight their ends stood apart 4 inches instead of closing up to form a V. Tank C was extended by a trough 19 feet long, in which partition walls were constructed continuing the partitions in the lower portion up to a section, 38, above the zero in Tank C; these were straight, vertical boards, the distance between them contracting from 4 inches at the lower end to 1 inch at the end of the river.

Tank F′ was formed in a similar manner, except that the upper extension was bent through two sharp right angles so as to return along the side of the tank; and subsequently Tank F was formed exactly similar to Tank E with half the dimensions.

Experiment with Land Water, I. and II., Tanks E and F′, Plates XIII.–XVII., July 11 *to July* 31.—In Tank E the sand was laid to a depth of 4 inches, the same as in C, from the upper end of the river, Section 38 down to Section 28. The rise of tide was 0·140 foot, and the mean level of the tide about ·016 foot above the level of the sand. The period 49 secs. and water 1 quart a minute, or 1/200 the tidal capacity per tide, was introduced at the upper end of the river.

In Tank F′ the sand was laid similar to that in Tank E, the rise of tide 0·1 foot, and the mean tide 0·006 foot above the level of the sand. The period being 30·04, land water, 1/200 the capacity of the estuary, was introduced at the top of the river.

In starting these experiments the effect of the tidal river was very marked. After the first tide in Tank E some depth of water remained in the river and a long way down the estuary at low water, and the tide came up with a bore increasing in height all the way to the top of the river, and then returned with a bore to the lower end of the river. The bore, as before, soon died out over the greater part of the estuary as the sand at the bottom became lower. And the bore gradually died out in the top of the V until as the number of tides approached 16,000 the bore only began to show at about Section 4 and ran up the river very much diminished from what it was originally.

Owing to the indraught and outflow of the river, the velocity of the water and its action on the sand was greater at the top of the V and the mouth of the river than at any part of the estuary, while for some way up the river and all the way down the estuary there was a large volume of water running at low water. The top of the river was ninety miles (reduced to a 30-foot tide) from the bottom of the estuary, and the tide did not commence to fall at the top of the river until after low water at the mouth, so that nearly all the tidal water in the river ran over the estuary during the low water. The delay in the return of the water from the river obviously played a most important part in the effects produced.

At the bottom of the estuary the sand came down much as usual, but it did not rise at the head of the estuary. For the first 10,000 tides the sand was all covered at low water and rippled with active ripples up to the end of the river, and it seemed as if no banks were going to appear. The sections of the sand appeared as nearly as possible horizontal. The level having lowered from the bottom of the estuary up to Section 15, from Section 15 to Section 3 it was somewhat raised, then from 3 upwards to 7 it was lowered, and thence up to the top of the river it was raised in a gradual slope. At about 12,000 tides two small banks appeared at low water, one on each side of the estuary at Section 13. Everything was perfectly symmetrical so far, but from this time the bank on the right of the estuary extended downwards, while that on the left extended upwards and a depression or channel formed between them extending across the estuary in a diagonal manner. This was the condition when at 16,000 tides the first survey was made.

As the running continued these banks continued to rise, that on the right downwards, that on the left upwards, until a distinct channel was formed from the mouth of the river down to Section 20, as shown in the second survey at 32,000 tides.

The level of the sand at the mouth of the river altered very little, diminishing during the first 10,000 tides and then reassuming its original height, but the sand passed upwards through the mouth and gradually raised the level in the river above until there was only about 0·02 foot in the shallowest places at low water (corresponding to 5 foot on a 30-foot tide); this level was first reached at the top of the river and then gradually extended down to Section 19, which point it had reached at 32,000 tides when the second survey was taken. In this condition the bore still reached the end of the river, raising the water 0·02 foot (5 feet on the 30-foot tide). Above Section 19 all motion of the sand had ceased, but below this the sand was still moving up when the experiment stopped. The bore still formed at the mouth but very much diminished, and was very slowly diminishing. The final condition of the estuary shows the contour at low water in the generators extending up to Section 9, and the contour at high water in the generator to Section 11.

In tank F′ with the sharp turns in the river the action of the sand at the bottom of the tank was at first sluggish, as in Experiment IV. In the top of the estuary and river the appearance of things for the first 10,000 tides was much the same as in Tank E, except that the ripple of the sand did not extend more than half-way up the river and deep holes were formed at the bends, banks being formed between them. The bore, however, ran up to the end of the river until some time after the first survey was taken, and the tide still rose very slightly when the second survey was made, though the river was barred by a bank between the bends by which the flood just passed in small channels at the sides. The sand had risen in the top of the estuary until it virtually closed the mouth of the tidal river, and the condition of the estuary resembled that obtained in Tank D. This virtually ended the experiment, but opportunity was taken to try the effect of a larger quantity of land water, which was increased to one quart in two minutes—*i.e.*, nearly three times—and the experiment continued for 20,000 more tides without any material effect.

In Tank F the action at the lower end of the tank was again sluggish. At the top of the estuary and in the river the conditions of the sand were as near as possible similar to those in Tank E, but, as it came out, the mean level of the water relative to the level of the sand was some 5 feet (reduced to a 30-foot tide) lower in F than in E.

The appearances for the first 16,000 tides were the same as far as was observed; the ripple now extended up to the top of the river and no banks formed at the mouth. Nevertheless, before the second survey was taken, the tide ceased to rise above the mouth of the river, proving that the previous failure to realise the same state in the small tank as in the larger had not been entirely due to the bends in the river. The question remained whether it might not be owing to the higher level of the sand relative to the mean level of the tide.

This question brings into prominence a fact observed during all the experiments, but which had not previous to the experiments on E and F assumed a position of importance. This is the *gradual diminution of the rise of tide owing to the lowering of the sand.*

29. The rise of the tide depends not only upon the rise of the generator, but also upon the tidal capacity of the tank. This capacity is the product of the area of the surface at high water multiplied by the rise of tide less the volume of sand and water above low water in the generator. Now in starting the experiments with the sand at the level of mean tide, not only is there much more sand above the level of low water in the generator than when the final condition of equilibrium is obtained, but the quantity of water retained on the top of the level sand is considerable, so that the tide rises considerably higher in the generator at starting than when the condition of equilibrium is obtained, which excess of rise gradually diminishes as the sand comes down at the lower end of the estuary.

Although the foot of the sand comes down pretty rapidly at the commencement of the experiment, owing to the surface being rippled the water runs off slowly, and it is not till the sand at the head of the estuary has been raised and a slope formed that the water runs down freely at low water, so that during the early part of the experiment not only is the rise of tide at the head of the estuary high, but also the low tide and the mean level of the tide. The result is that the mean level of the water at the head of the estuary is higher during the early part of the experiment. These changes in the tide at different parts of the estuary and at different stages of the tide are well shown by the automatic tide curves, Plate XVIII. As the sand is rising at the top of the estuary the result of the high water is to raise the first banks above the level to which the tide finally rises.

As these banks come out and the ripple is washed off, leaving smooth surfaces and channels from which the water runs, leaving clean dry banks, the mean level as well as the rise of tide falls, leaving the tops of the bank, which were at first covered, high and dry.

These effects were much greater in Experiments C and D than in A and B, and still more marked in E, F′, and F. In E, F, F′, the plans 1 and 2, taken at 16,000 and 33,000 tides respectively, show the difference in the level of the sand at the mouths of the respective rivers. In Tank E the rise of tide at the mouth of the river was observed to be 0·02 higher at 16,000 than at 33,000 tides, and in Tanks F and F′ at 16,000 tides there was a bore which ran up to the top of the river, while at 33,000 tides the sand at the mouth was not covered at high water.

It thus seems that the condition of things which follows from starting with the sand level and a constant height of low water is to institute a distribution of sand at the top of the estuary corresponding to a state of equilibrium with a higher tide than that which ultimately prevails; and the greater the initial height of the sand relative to the mean level of the water the greater will be this effect. That this action tends to explain the closing of the mouths of the rivers in Tanks F′ and F and not in E is clear. But it is not clear that this is the sole explanation; the conditions in F′ and F were not far removed from the limits of similarity obtained in the rectangular tanks, and it is not clear that these limits may not be somewhat different in the long estuaries with tidal rivers. This is a matter which requires further experimental examination, for which there has not been time.

30. *Experiment II. in E and F, Plates XV. and XVI., without Land Water, August 5 to September* 1.—These experiments have been made under the same conditions as in E and F, 1, except for the landwater. The general appearance of the progress of the experiments was nearly the same, and Plan 1 shows little difference. But as the experiment in E proceeded it became clear that the river was going to fill up gradually from the end. The bore no longer reaches the end at 16,000 tides, while it had ceased to exist and the tide had ceased to rise at Section 11 in the river at 32,000 tides, the end of the estuary also having filled up, the action in F being nearly the same. Thus we have evidence similarly shown by both estuaries that, although the fresh water produces little effect on the condition of equilibrium of a broad estuary, the existence of a long tidal river above the estuary does produce a great effect on the level of the low-water channels in the upper portions of the estuary, and that land water, even in such small quantities, is effective to keep open a long tidal river emptying into a sandy estuary or bay.

TABLE I.—*General Conditions*

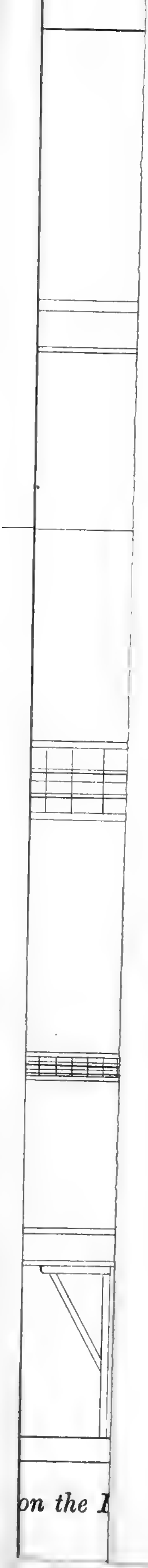
Shape of the Estuary	Percentage of Land Water	References				Period in seconds	Horizontal scales		Vertical scale 1 in.	Rise of tide in feet	Vertical exaggeration *e*
		Experiment	Tank	Plan	Plate		1 in.	Inches to a mile			
Rectangular	0·0	VII	A	2	III	33·5	17,600	3·58	177	0·170	99·7
	„	III	B	2	„	23·8	33,600	1·88	327	0·094	102·0
	„	„	„	3	„	23·8	33,600	1·88	327	0·094	102·0
	„	IV	„	1	„	34·4	23,300	2·71	327	0·094	71·0
	„	IX	A	1	IV	69·3	10,500	6·02	333	0·090	31·6
	„	V	B	1	„	50·5	23,600	2·68	720	0·042	32·0
	„	IX	A	2	„	69·3	12,400	5·08	379	0·080	32·0
	„	„	„	3	„	67·3	12,600	5·02	366	0·082	34·5
	„	VII	B	1	V	34·0	39,200	1·57	986	0·030	39·0
	„	„	„	2	„	34·0	39,200	1·57	986	0·030	39·0
	0·6	X	A	1	VI	50·2	11,500	5·49	171	0·176	67·0
	1·2	VIII	B	1	„	35·4	22,000	2·87	309	0·097	71·0
	0·6	X	A	2	„	48·6	11,900	5·30	171	0·176	69·0
	1·2	VIII	B	2	„	34·5	22,600	2·8	309	0·097	73·0
	0·6	X	A	3	VII	48·6	11,900	5·30	171	0·176	69·0
	1·2	VIII	B	3	„	34·5	22,600	2·8	309	0·097	73·0
Short V-shaped	0·0	XI	A	1	VIII	47·5	12,400	5·10	177	0·170	71·0
	„	X	B	1	„	35·4	20,700	3·05	273	0·110	75·8
	„	XI	A	2	„	47·2	12,670	5·01	181	0·166	69·5
	„	X	B	2	„	35·4	20,700	3·05	273	0·110	75·8
	0·7	XI	A	3	IX	47·2	12,400	5·08	177	0·170	70·0
	0·7	X	B	3	„	34·0	21,800	2·90	280	0·107	78·0
	0·7	XII	A	1	X	48·2	12,300	5·15	179	0·168	68·4
	0·7	XII	B	1	„	34·2	21,700	2·91	280	0·107	77·6
	0·7	XII	A	2	„	47 0	12,700	5·00	182	0·165	69·4
	0·7	XII	B	2	„	34·2	21,900	2·88	286	0·105	75·0
Long V-shaped	—	I	C	1	XI	49·8	12,100	5·22	185	0·162	65·4
	—	I	D	1	„	35·9	20,900	3·03	285	0·105	73·1
	—	I	C	2	„	46·2	13,200	4·78	190	0·158	69·5
	—	I	D	2	„	34·4	21,800	2·90	286	0·105	76·0
	0·6	II	C	1	XII	48·4	12,500	5·04	188	0·160	66·8
	0·6	II	D	1	„	34·6	22,200	2·85	300	0·100	74·1
	0·6	II	C	2	„	48·4	12,500	5·04	188	0·160	66·8
	0·6	II	D	2	„	34·6	22,200	2·85	300	0·100	74·1
Long with Tidal River	0·5	I	E	1	XIII	48·9	13,100	4·82	208	0·143	63·2
	0·5	I	F	1	„	30·0	25,800	2·45	313	0·096	82·5
	0·5	I	E	2	XIV	47·8	13,400	4·70	208	0·143	64·6
	0·5	I	F	2	„	30·0	24,700	2·56	313	0·096	82·5
	0·0	II	E	1	XV	47·9	13,500	4·67	214	0·140	63·4
	„	II	F	1	„	31·5	25,400	2·49	327	0·091	77·8
	„	II	E	2	XVI	47·9	13,600	4·64	217	0·138	62·9
	„	II	F	2	„	30·3	26,200	2·41	321	0·093	81·86
	0·5	I	F′	1	XVII	30·1	25,500	2·48	300	0·100	85·1
	0·5	I	F′	2	„	30·1	25,700	2·46	305	0·098	84 4

and Results of the Experiments.

Criterion of similarity $C=h^3e$	Height of initial sand in feet	Height of mean tide in feet	Number of tides from the start	Action of the water on the sand in forming the bed at the lower end of the estuary		
				Manner	Rate	Final state
0·490	0·25	0·265	93,839	General	Normal	—
0·083	0·125	0·140	99,388	General	Normal	Normal
0·083	0·125	0·140	130,176	—	—	Large ripple
0·058	0·125	0·130	16,344	Nearly normal	Nearly normal	Nearly normal
0·023	0·125	0·1325	13,078	Very partial	Very slow	—
0·002	0·65	0·065	17,919	—	Zero	—
0·016	0·125	0·142	36,776	—	—	—
0·019	0·125	0·141	78,986	—	—	Not reached
0·001	Slope 1 in 124	0·065	17,424	—	Zero	—
0·001		,,	39,727	—	—	Nearly normal
0·252	0·25	0·256	19,437	Normal	Normal	—
0·064	0·125	0·148	18,332	Nearly normal	Nearly normal	—
0·362	0·25	0·256	42,820	—	Normal	Normal
0·066	0·125	0·148	68,861	—	—	—
0·362	0·25	0·256	76,273	See description	—	See description
0·066	0·125	0·148	91,184	See description	—	See description
0·346	0·333	0·337	17,206	Normal	Normal	—
0·101	0·166	0·179	17,879	—	Normal	—
0·320	0·333	0·348	39,809	—	—	Normal
0·101	0·166	0·169	40,268	—	—	Normal
0·343	0·333	0·348	60,243	Normal	Normal	Normal
0·095	0·166	0·169	57,024	Normal	Normal	Normal
0·327	0·333	0·340	16,538	Normal	Normal	—
0·095	0·166	0·168	15,981	Normal	Normal	—
0·315	0·333	0·343	31,991	Normal	Normal	Normal
0·081	0·166	0·175	35,129	Normal	Normal	Normal
0·278	0·333	0·341	16,943	Normal	Normal	—
0·084	0·187	0·179	16,383	Nearly normal	Nearly normal	—
0·275	0·333	0·345	30,584	Normal	Normal	Normal
0·088	0·187	0·179	35,344	Nearly normal	Nearly normal	Nearly normal
0·274	0 333	0·344	16,908	Normal	Normal	—
0·074	0·187	0·190	18,128	Nearly normal	Nearly normal	—
0·274	0·333	0·335	31,127	Normal	Normal	Normal
0·074	0·187	0·190	31,928	Nearly normal	Nearly normal	Nearly normal
0·185	0·333	0·350	16,368	Normal	Normal	—
0·073	0·187	0·191	16,577	Partial	Sluggish	—
0·189	0·333	0·337	32,635	—	Normal	Normal
0·073	0·187	0·191	32,880	—	—	Ripple large
0·174	0·333	0·349	15,871	Normal	Normal	—
0·060	0·187	0·193	17,184	Partial	Sluggish	—
0·163	0·333	0·349	32,501	—	—	Normal
0·066	0·187	0·192	29,947	—	—	Ripple large
0·085	0·187	0·187	16,577	Partial	Sluggish	—
0·080	0·187	0·187	32,677	—	—	Ripple large

TABLE II.—*Mean Slopes of the Sand in Rectangular Tanks.*

Measured Heights of Contours shown on the Plan	TANK A: Experiment V., Plan 4: Height (reduced to a 30-foot Tide) of Contours from L.W.	Mean Horizontal Distance of Contours from the Contour at 30 feet above L.W.	Horizontal Distances reduced to a 30-foot Tide	TANK A: Experiment VII., Plan 2: Height (reduced to a 30-foot Tide) of Contours from L.W.	Mean Horizontal Distance of Contours from the Contour at 30 feet above L.W.	Horizontal Distances reduced to a 30-foot Tide
Feet	Feet	Unit 6 inches	Miles	Feet	Unit 6 inches	Miles
1	—	−0·975	−1·65	—	−1·792	−3·003
0·176	30·00	0·00	0·00	30·000	0·000	0·000
0·146	24·39	0·79	1·355	24·546	0·647	1·133
0·116	18·68	1·86	3·20	19·092	1·254	2·171
0·086	13·00	2·96	5·07	14·638	2·356	4·085
0·056	7·46	4·64	7·95	9·184	3·724	6·447
0·026	1·87	6·63	11·38	3·730	5·428	9·397
−0·004	−3·74	8·43	14·50	−1·724	7·467	12·930
−0·034	−9·35	10·30	17·80	−7·178	9·283	16·070
−0·064	−15·00	12·17	21·60	−12·632	11·780	20·400
−0·094	−20·80	13·60	23·40	−18·086	14·003	24·235
−0·124	−26·20	15·88	27·30	—	—	—
	Experiment X., Plan 1			Experiment X., Plan 2		
Feet	Feet	Unit 6 inches	Miles	Feet	Unit 6 inches	Miles
1	—	−0·690	−0·774	—	−1·032	−1·167
0·176	30·000	0·000	0·000	30·000	0·000	0·000
0·146	24·886	0·741	0·810	24·886	0·665	0·752
0·116	19·772	2·147	2·347	19·772	1·900	2·149
0·086	14·658	4·256	4·652	14·658	3·648	4·124
0·056	9·544	6·916	7·560	9·544	6·631	7·507
0·026	4·430	9·880	10·800	4·430	9·101	10·290
−0·004	−0·684	11·533	12·606	−0·684	11·227	12·594
−0·034	−5·798	13·737	15·013	—	—	—
	TANK B: Experiment III., Plan 2			TANK B: Experiment IV., Plan 1		
Feet	Feet	Unit 3 inches	Miles	Feet	Unit 3 inches	Miles
1	—	−3·540	−5·643	—	−0·994	−1·124
0·094	30·000	0·000	0·000	30·000	0·000	0·000
0·079	25·213	0·760	1·240	25·213	0·665	0·760
0·064	20·426	1·330	2·163	20·426	1·558	1·773
0·049	15·639	2·052	3·340	15·639	2·185	2·487
0·034	10·852	3·249	5·290	10·852	4·142	4·714
0·019	6·065	4·332	7·044	6·065	6·859	7·806
0·004	1·278	6·061	9·854	1·278	9·766	11·120
−0·011	−3·509	7·828	12·727	−3·509	12·046	13·710
−0·026	−8·296	9·291	15·110	−8·296	—	—
−0·031	−13·083	11·341	18·430	—	—	—
	Experiment VIII., Plan 1			Experiment VIII., Plan 2		
Feet	Feet	Unit 3 inches	Miles	Feet	Unit 3 inches	Miles
1	—	−0·595	−0·621	—	−1·925	−2·062
0·097	30·000	0·000	0·000	30·000	0·000	0·000
0·082	25·360	0·608	0·634	25·360	0·988	1·060
0·067	20·720	2·090	2·181	20·720	1·672	1·792
0·052	16·080	3·268	3·410	16·080	2·983	3·197
0·037	11·440	5·244	5·472	11·440	5·168	5·538
0·022	6·800	8·987	9·378	6·800	8·398	9·000
0·007	2·160	11·400	11·896	2·160	11·285	12·100
−0·008	−2·480	13·148	13·720	−2·480	13·108	14·050
−0·023	—	—	—	−7·120	14·535	15·570



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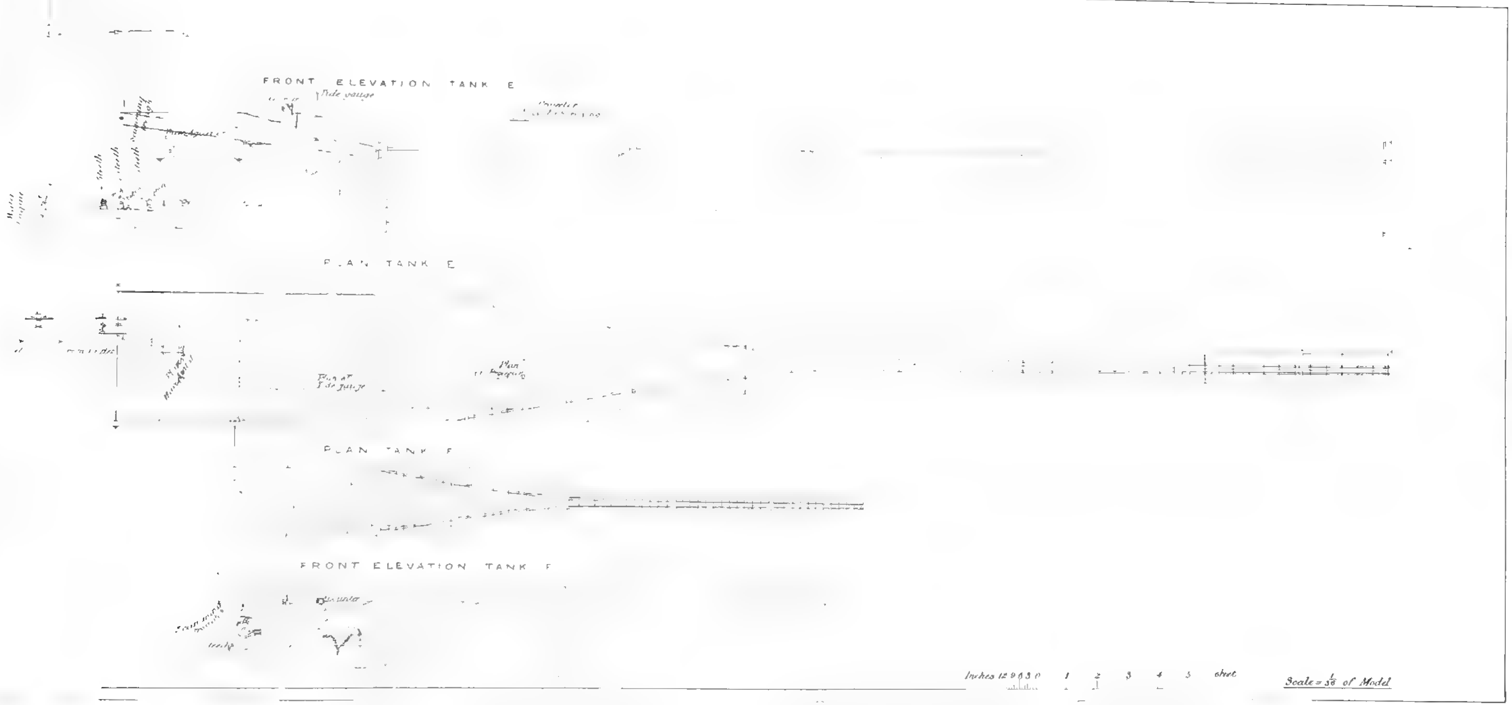

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Diagram of Actual Slopes with an exaggeration of 29.

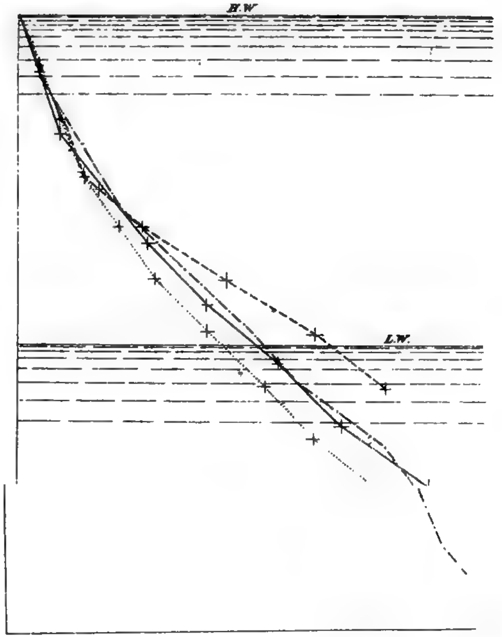
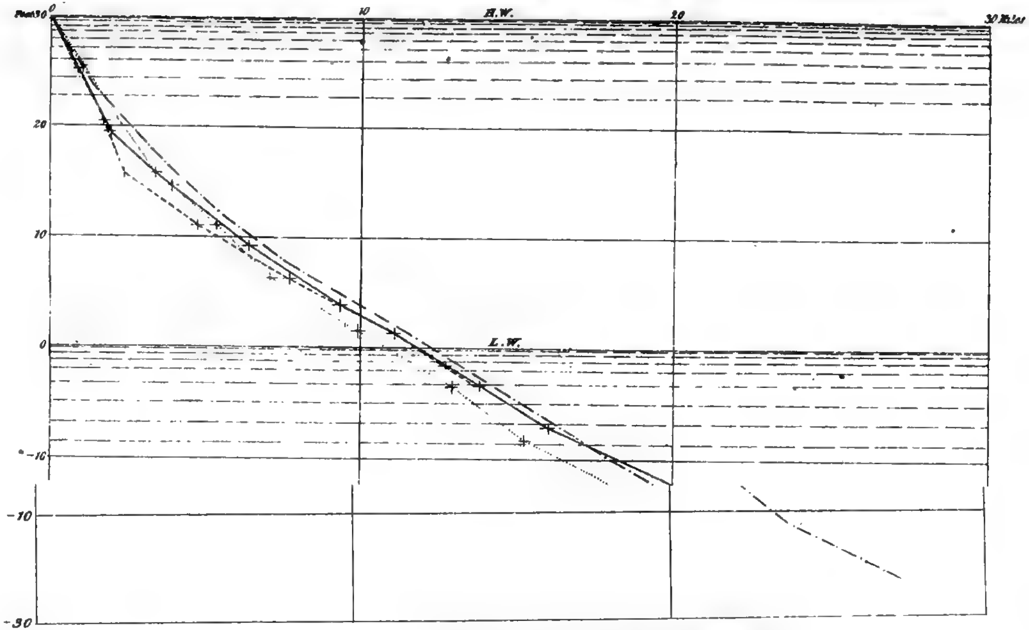


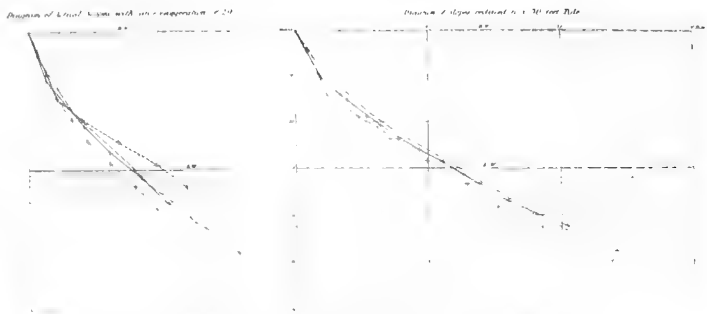
Diagram of slopes reduced to a 30 feet Tide.



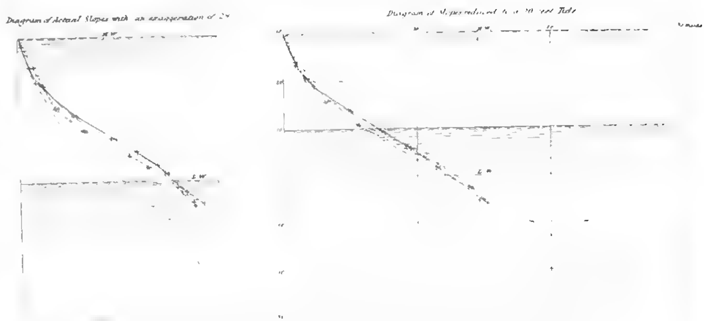
– – – – –	Tank A, Experiment V	Plan 4,	Period 33·3 Secs	Rise of Tide 0·161 Feet.	Without Land Water
————	" A "	X " 1	" 50·22 "	" 0·176 "	With Land Water.
············	" B "	VIII 1	" 35·43 "	" 0·097 "	With Land Water.
– – – – –	" B "	VIII 2	" 34·50 "	" 0·097 "	With Land Water.
–·–·–·–	" A "	X 2	" 48·60 "	" 0·176 "	With Land Water.

Illustrating the Report of the Committee for investigating the action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models.

Spottiswoode & Co Lith London.



Tank	A	Experiment	V	Plan	4	Period	33.3 Secs	Rise of Tide	0.161 Feet
"	A	"	VII	"	2	"	32.75	"	0.165
"	B	"	III	"	[illegible]	"	33.4	"	0.094
"	B	"	IV	"	1	"	[illegible]	"	0.094



Tank	A	Experiment	V	Plan	4	Period	33.3 Secs	Rise of Tide	0.161 Feet	Without Land Water
"	A	"	X	"	1	"	[illegible]	"	0.176	"
"	B	"	VIII	"	[illegible]	"	[illegible]	"	[illegible]	With Land Water
"	B	"	VIII	"	[illegible]	"	[illegible]	"	[illegible]	"
"	A	"	X	"	[illegible]	"	[illegible]	"	[illegible]	"

Illustrating the Report of the Committee for investigating the action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models.

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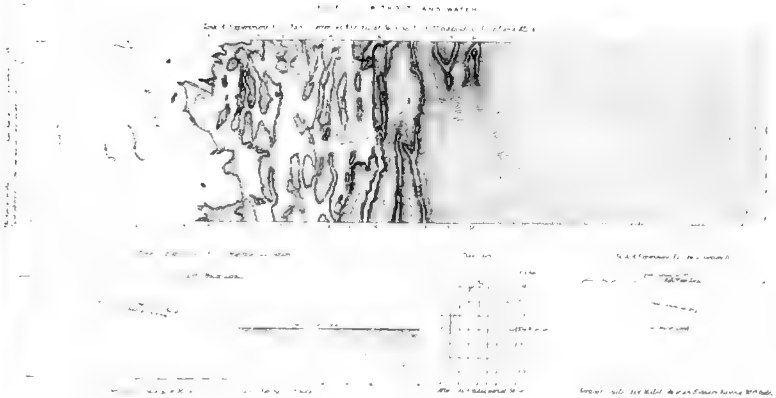
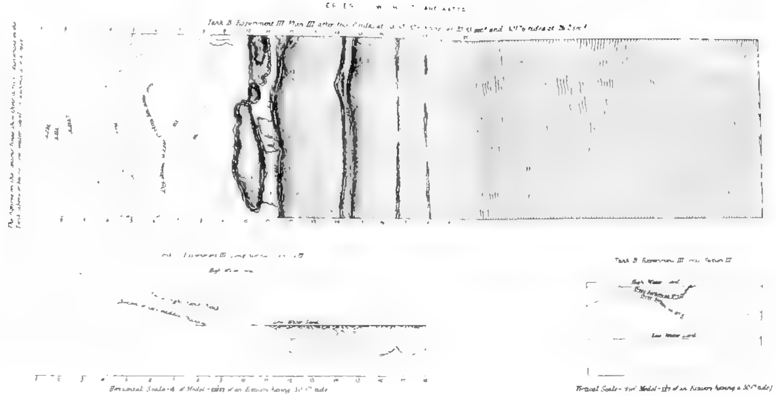
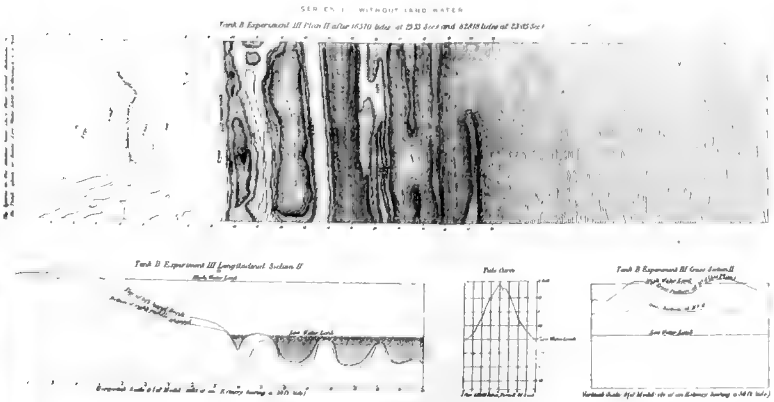
The figures on the Contour lines show their actual distances in the Tank above or below low water-level in decimals of a foot.

On a 30 ft. tide, distance between the sections represents about 1·6 miles

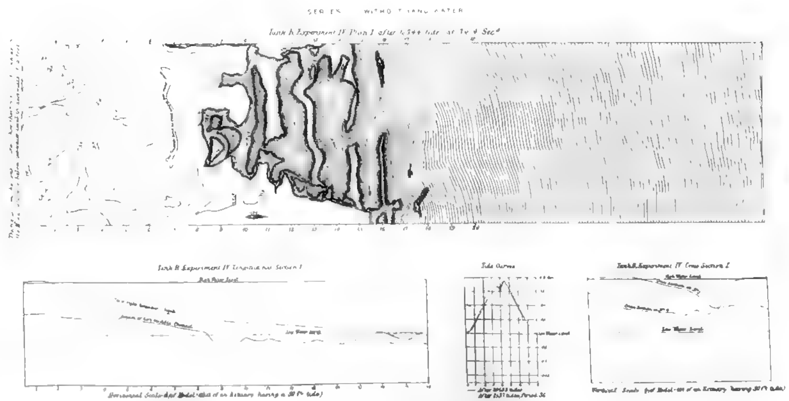




On a 30 ft. tide, distance between the sections represents 1·6 miles.



On a 30 ft. tide, distance between the sections represents 1·11 miles.



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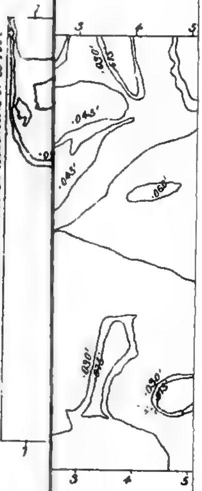
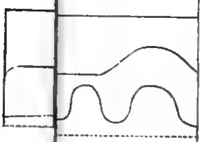
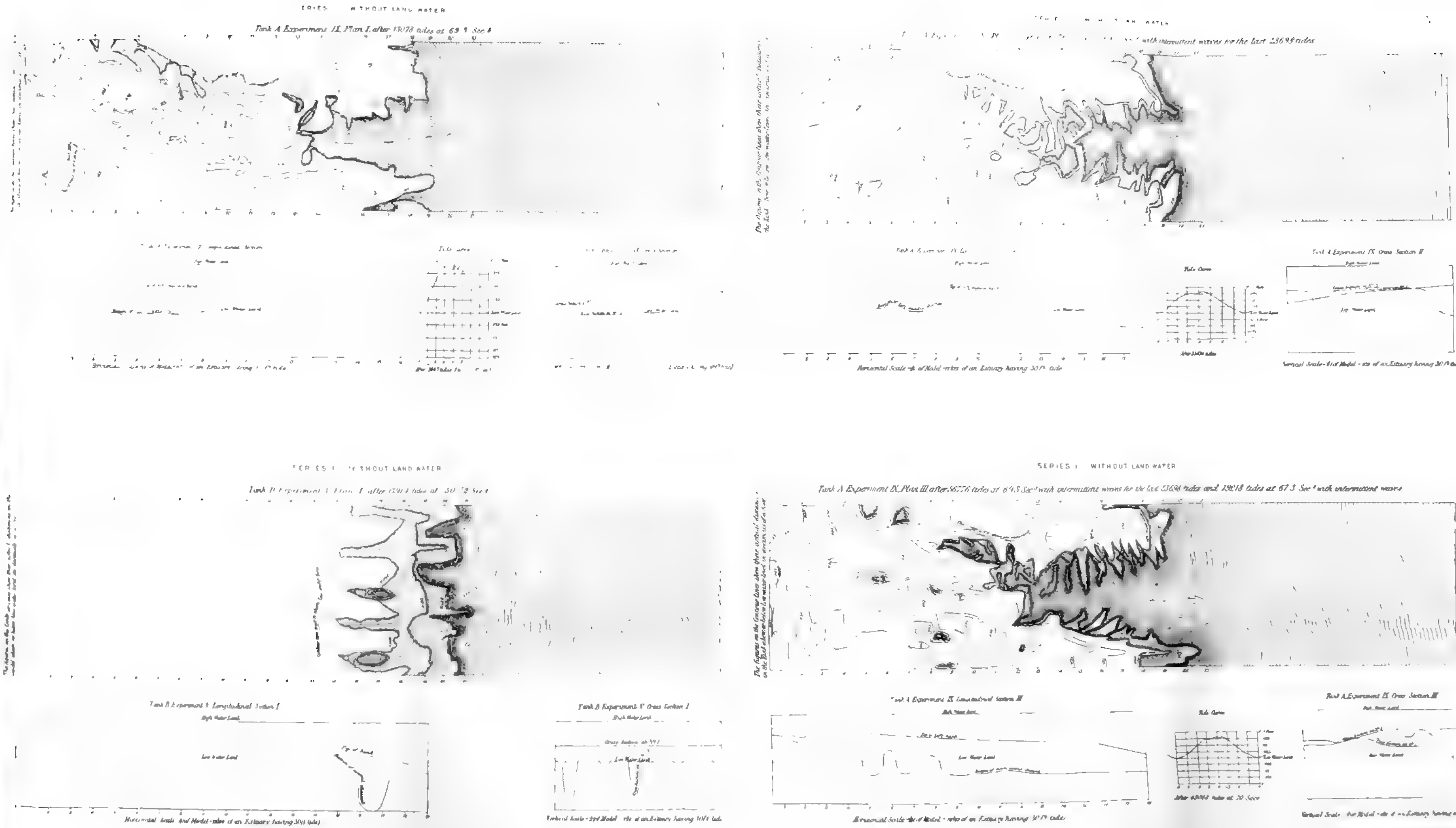
The figures on the Contour lines show their actual distances in the Tank above or below Low-water-level in decimals of a foot





On a 30 ft. tide, distance between the sections represents about 1·1 miles



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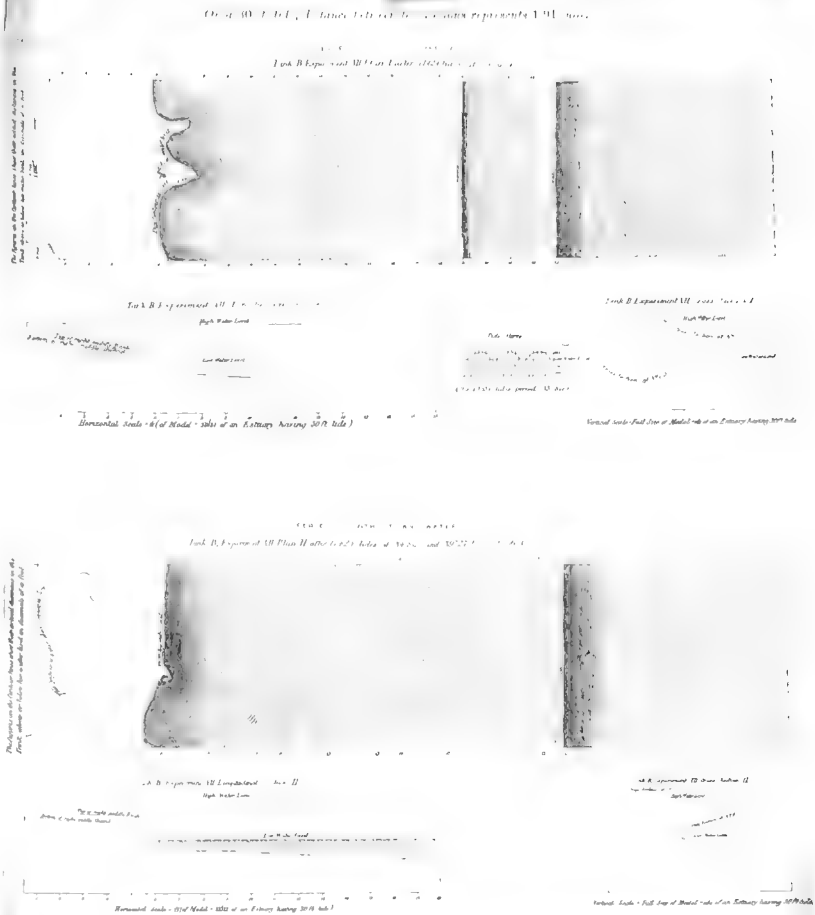

Illustrating the Report of the Committee for investigating the action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models.

The figures on the Con

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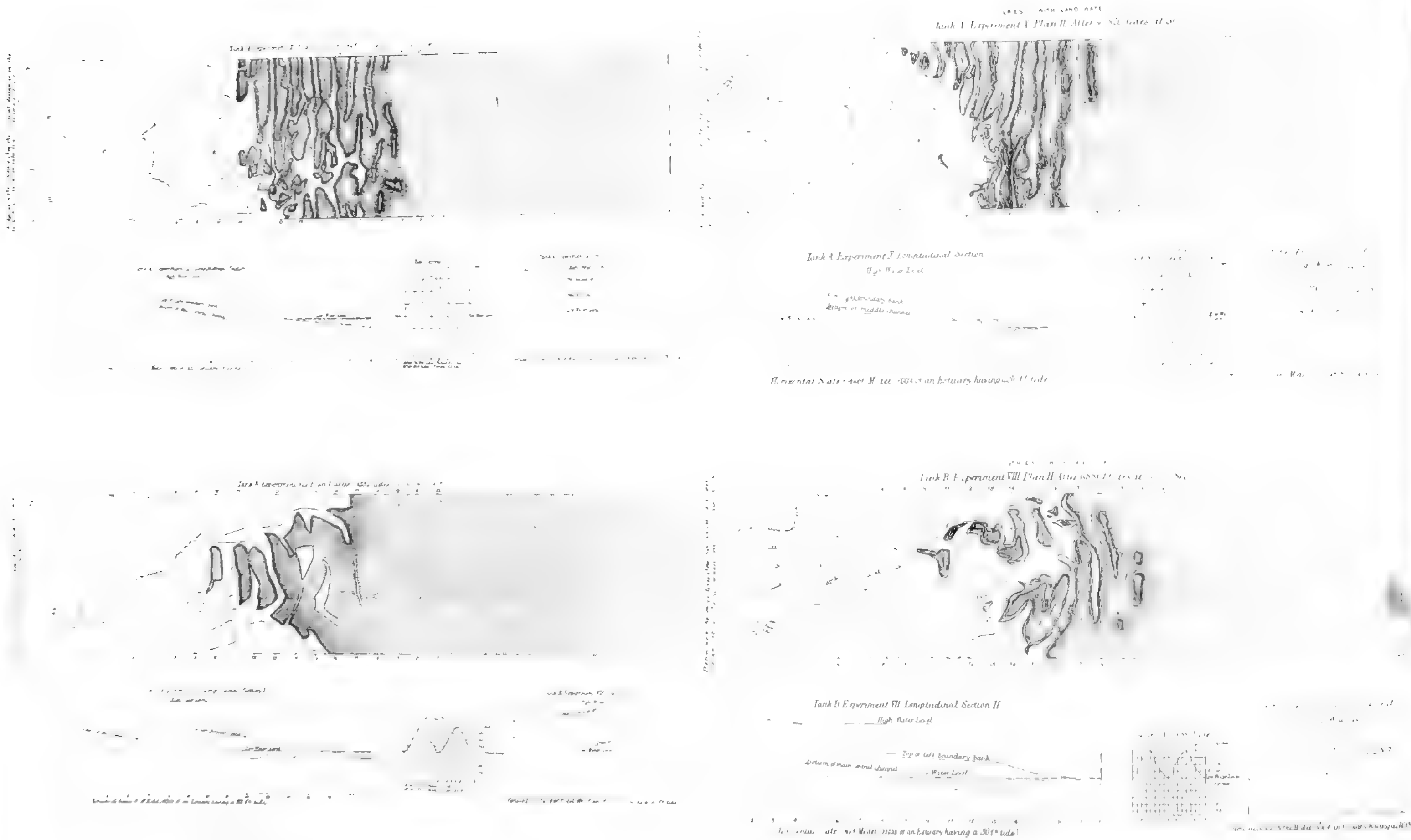
On a 30 ft. tide, distance between the sections represents about 1·1 miles.



Illustrating the Report of the Committee for investigating the action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models.

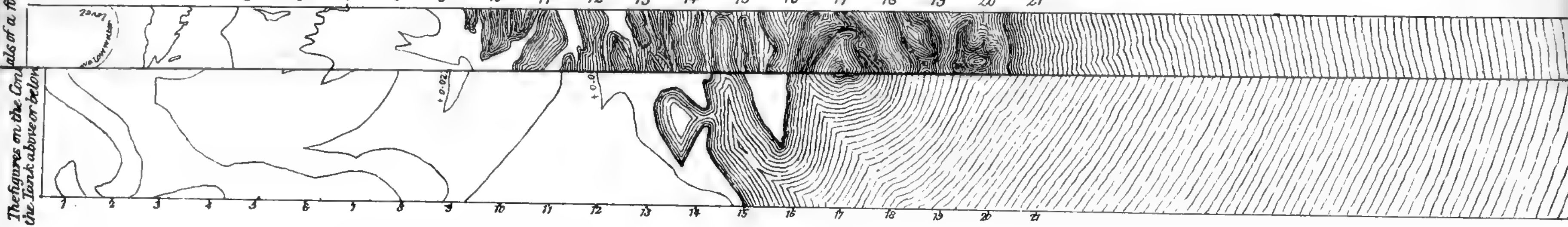
On a 30 ft. tide, distance between the sections represents about 1·1 miles.

On a 30 ft. tide, distance ... about 1·1 miles.

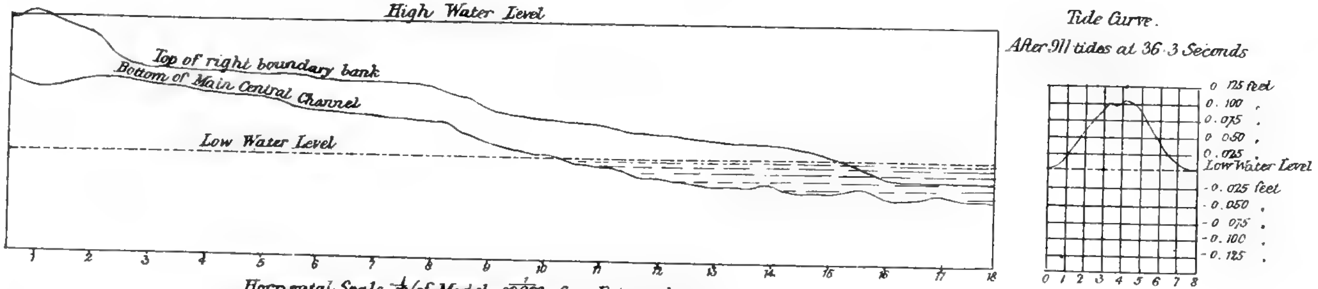
SERIES I WITH LAND WATER.

Plate VII

Tank A. Experiment X. Plan III. After 77574 tides at 49·8 seconds.

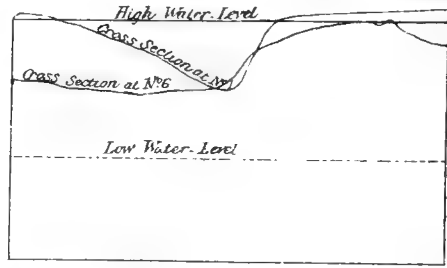


Tank B. Experiment VIII. Longitudinal Section



Horizontal Scale $\frac{1}{12}$ (of Model $\frac{1}{22633}$ of an Estuary having a 30 feet tide)

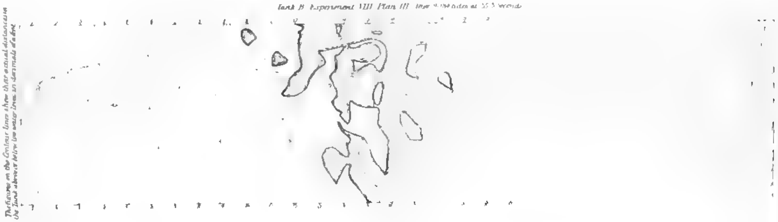
Tank B. Experiment VIII. Cross Section.



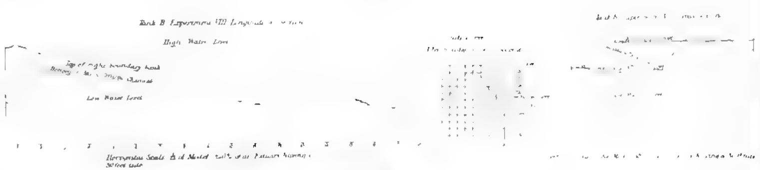
Vertical Scale $\frac{1}{2}$ (the Model $\frac{1}{309}$ of an Estuary having a 30 ft tide)

Spottiswoode & Co. Lith. London

High Water Line
Low Water Line

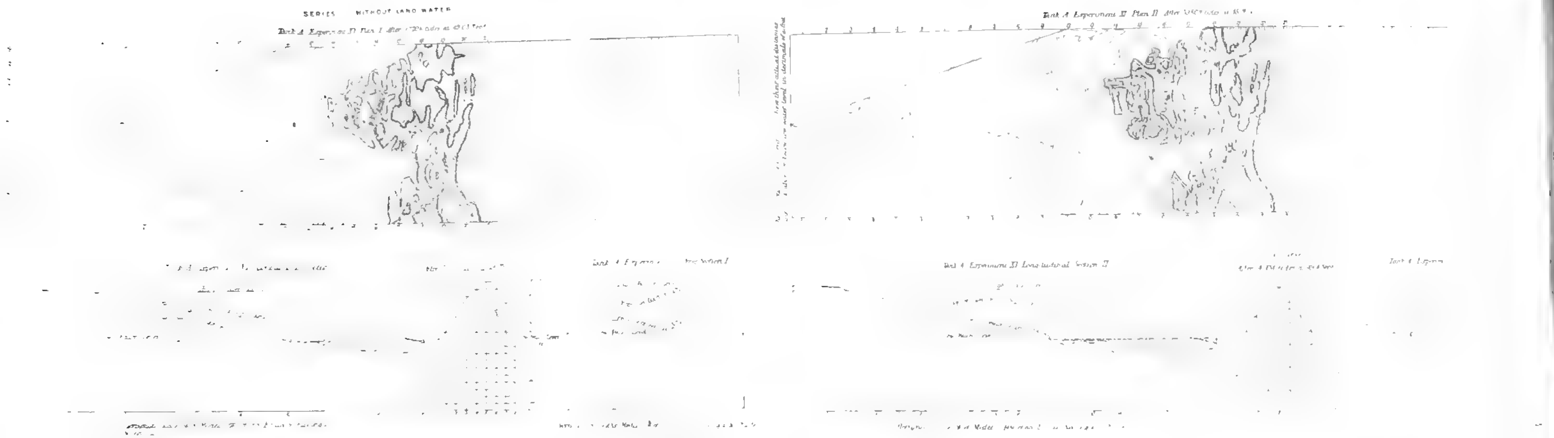


Tank B Experiment VIII Plan III
The figures on the Contour lines show their actual distances in the Tank above or below low water line in decimals of a foot

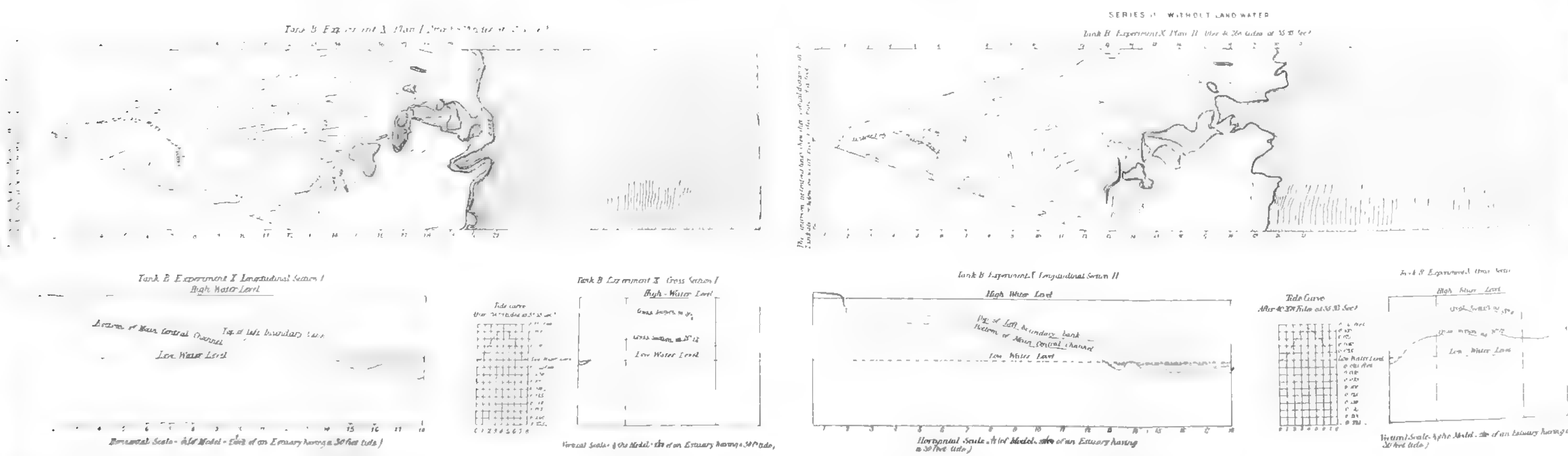


Tank B Experiment VIII Longitudinal Section
High Water Line
Top of right boundary bank
Low Water Level
Horizontal Scale
50 feet scale

On a 30 ft. tide, distance between the sections represents about 1·16 miles.



On a 30 ft. tide, distance between the sections represents 0·98 miles.



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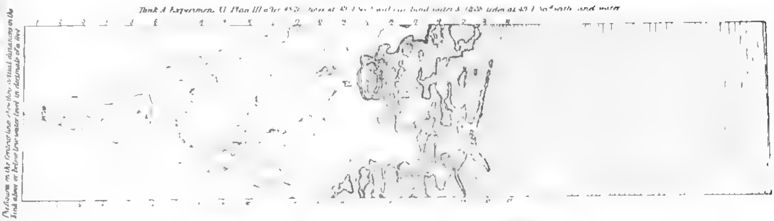
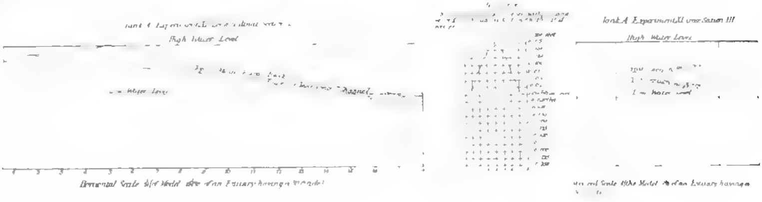
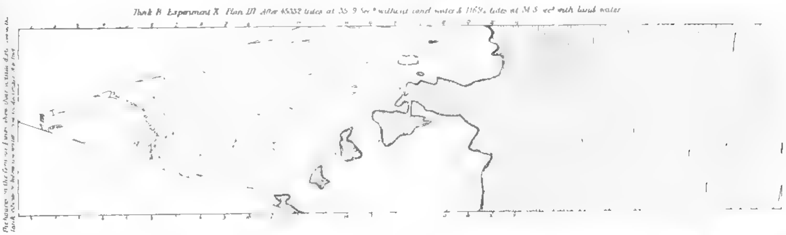
On a 80 ft. tide, distance between the contours represents about 1·1 miles.

60th Report Brit. Assoc. 1890.

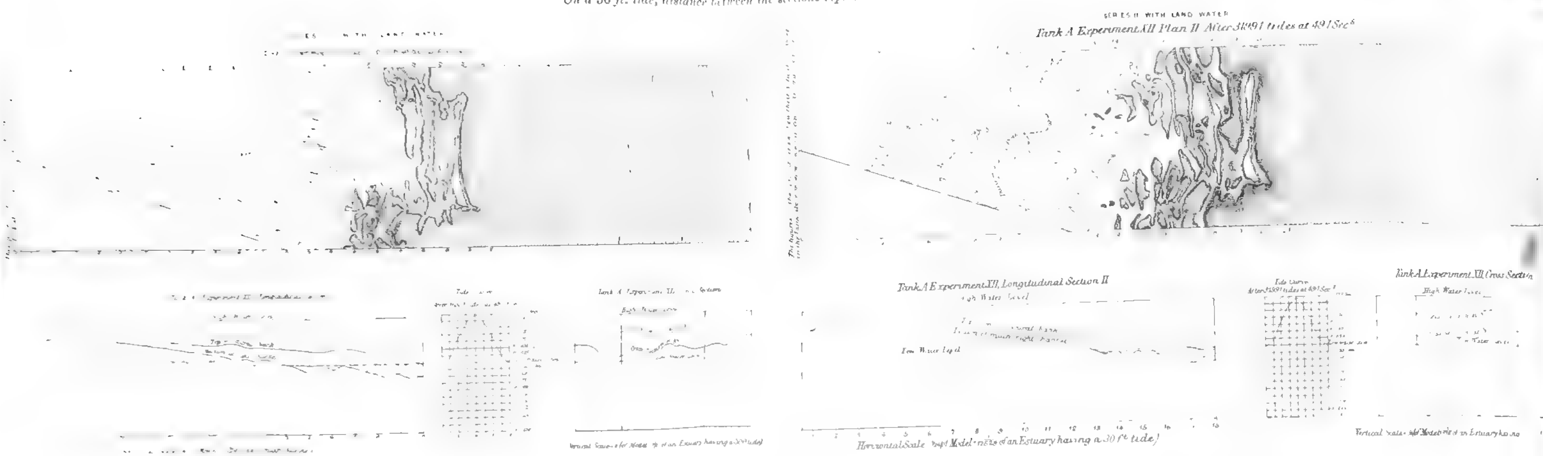
SERIES II. WITH LAND WATER.



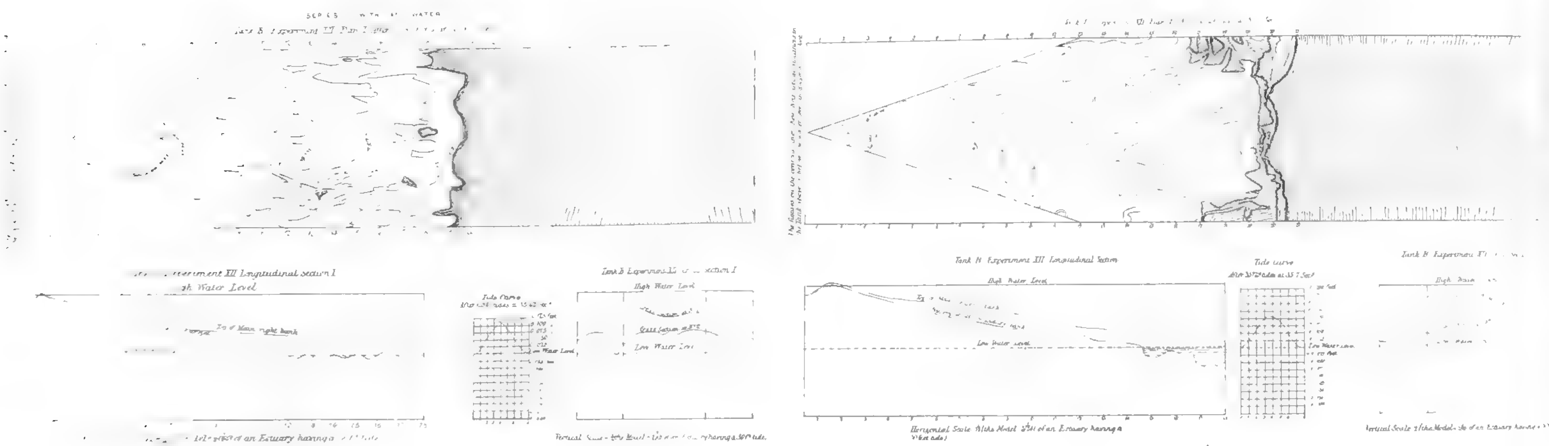




On a 30 ft. tide, distance between the sections represents about 1·2 miles.



On a 30 ft. tide, distance between the contours represents about 1·04 miles.



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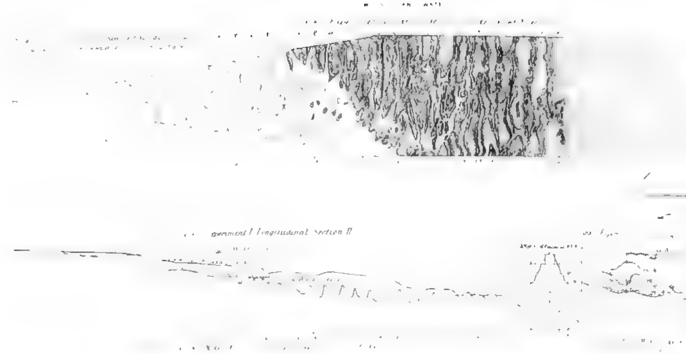
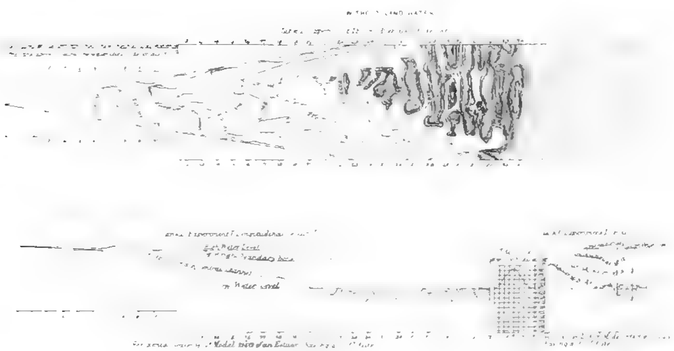
On a 30 ft. tide, distance between the sections represents about 1·2 miles.



On a 30 ft. tide, distance between the sections represents about 1 mile.



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The
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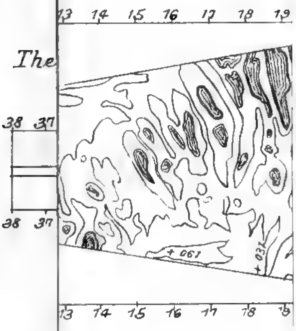
On a 30 ft. tide, distance between the sections represents 1·19 miles.

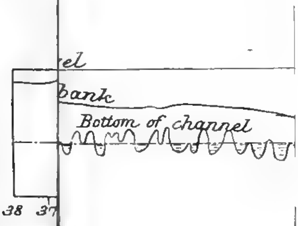
On a 30 ft. tide, distance between the sections represents 1·05 miles

Illustrating the Report of the Committee for investigating the action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models.

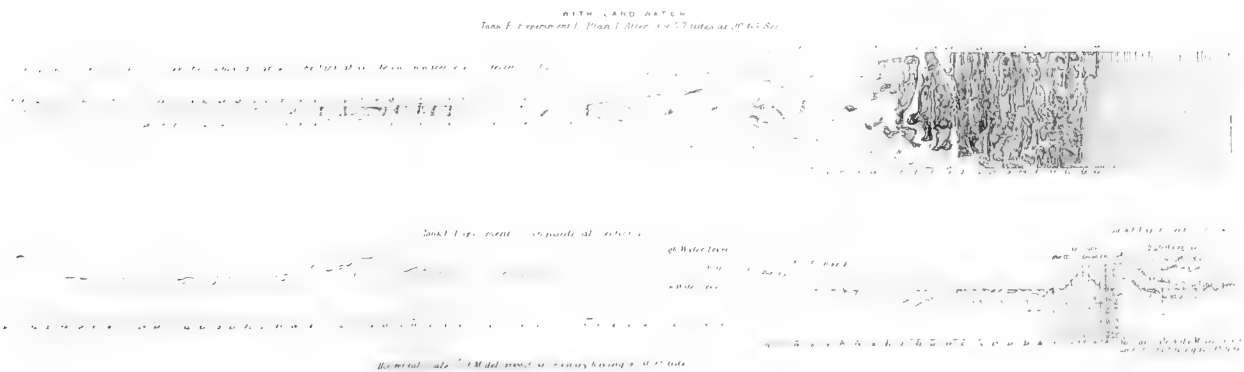
·24 miles.

·6 Sec.s





On a 30 ft. tide, distance between the sections represents about 1·24 miles.



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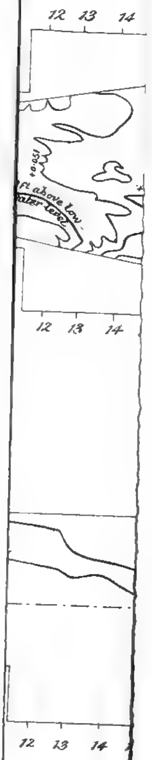

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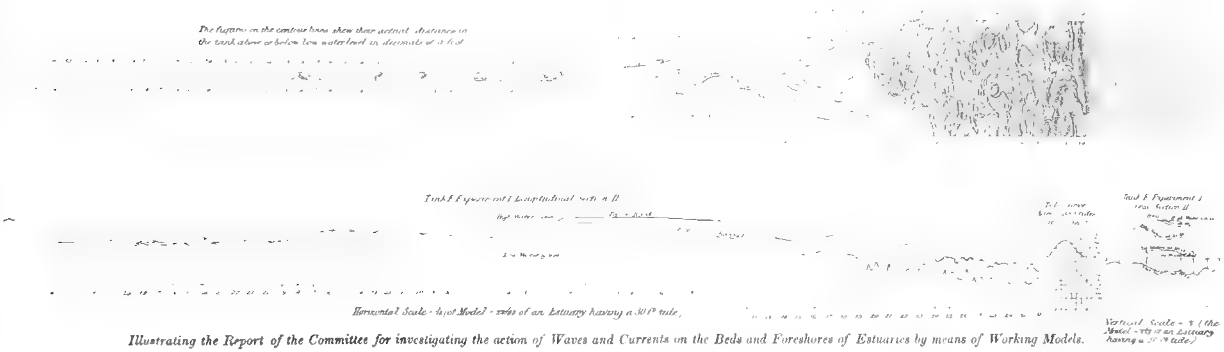
On a 30 ft. tide, distance between the sections represents about 1·2 miles.

WITH LAND WATER

WITH LAND WATER



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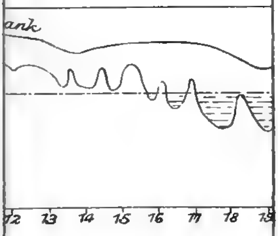
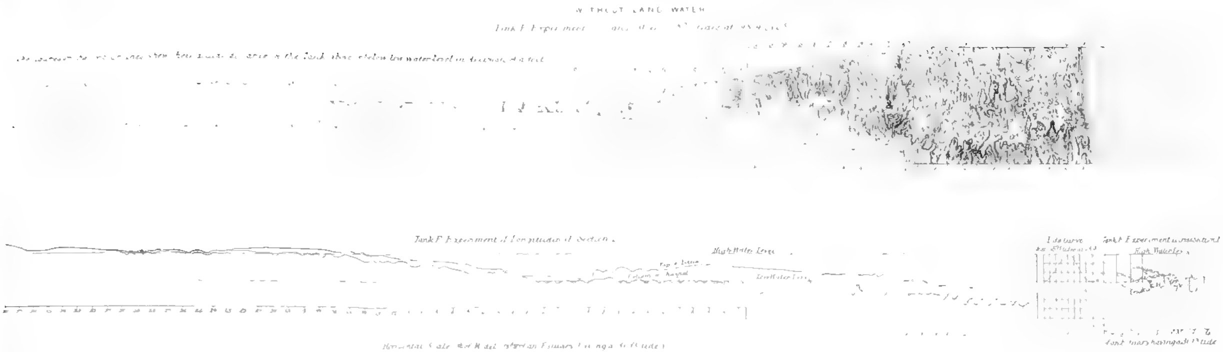


and Foreshores of

On a 80 ft. tide, distance between the sections represents about 1·25 miles.



Illustrating the Report of the Committee for investigating the action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models.

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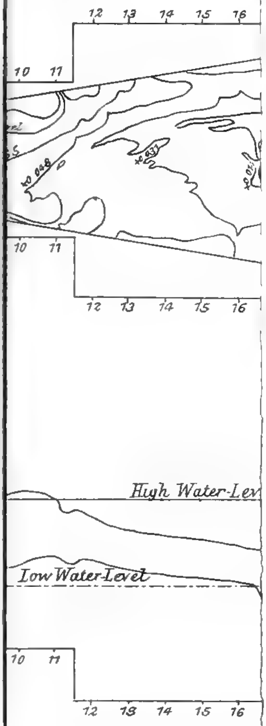
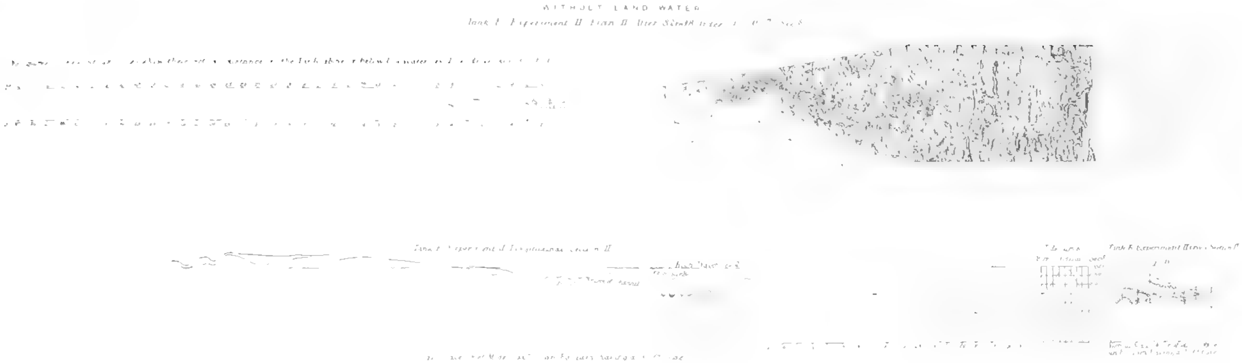
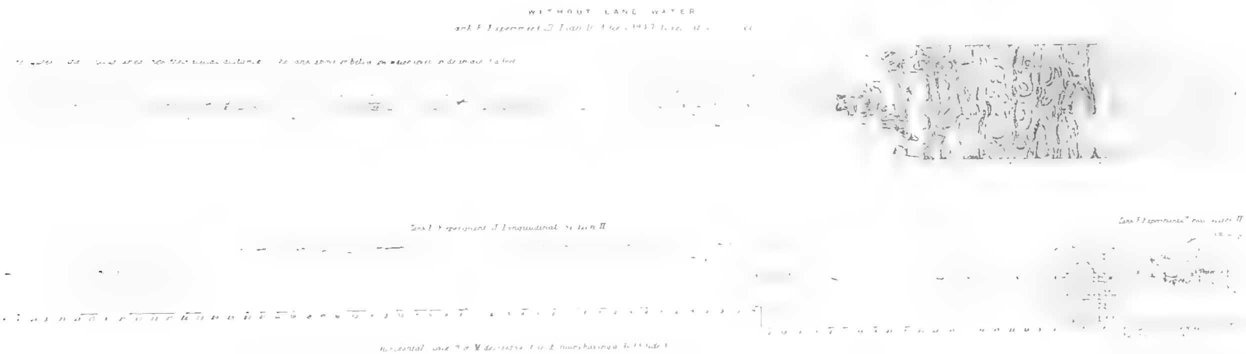


3eds and Foreshore

On a 30 ft. tide, distance between the sections represents about 1·25 miles.



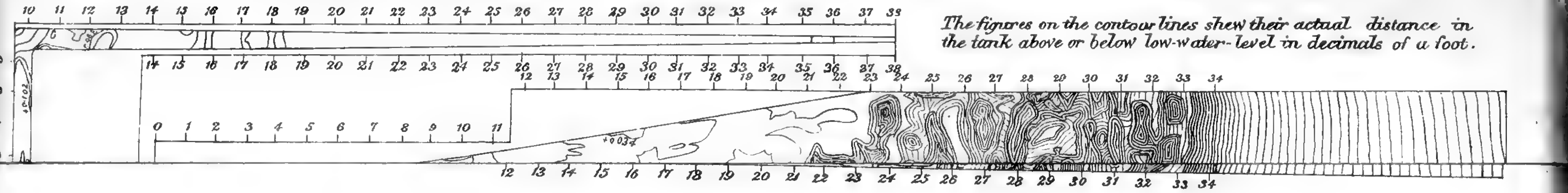


Illustrating the Report of the Committee for investigating the action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models.

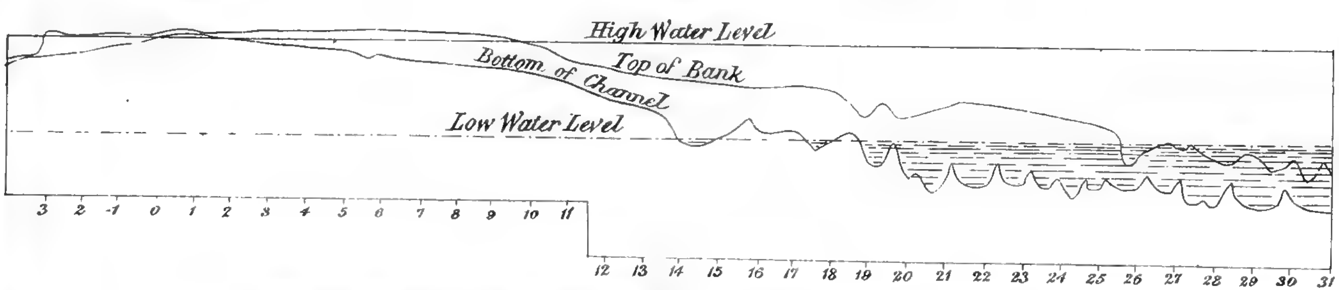
On a 30 ft. tide, distance between the sections represents 1·21 miles.

Tank F' Experiment I Plan I After 16577 tides at 34·51 Secs

The figures on the contour lines shew their actual distance in the tank above or below low-water-level in decimals of a foot.



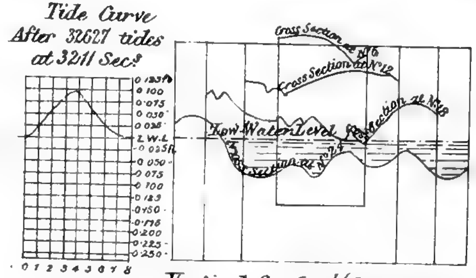
Tank F' Experiment I Longitudinal Section II.



Horizontal Scale = $\frac{2}{13}$ (of Model = $\frac{1}{23238}$ of an Estuary having a 30 ft tide)

Tank F' Experiment I. Cross Section II.

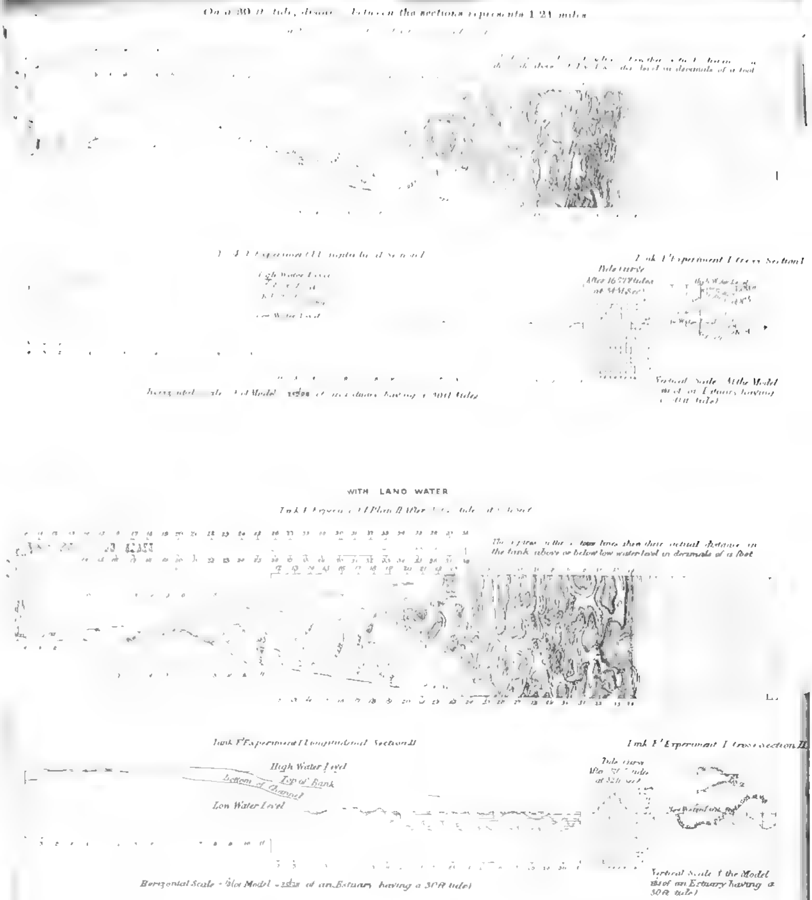
Tide Curve After 32627 tides at 3211 Secs



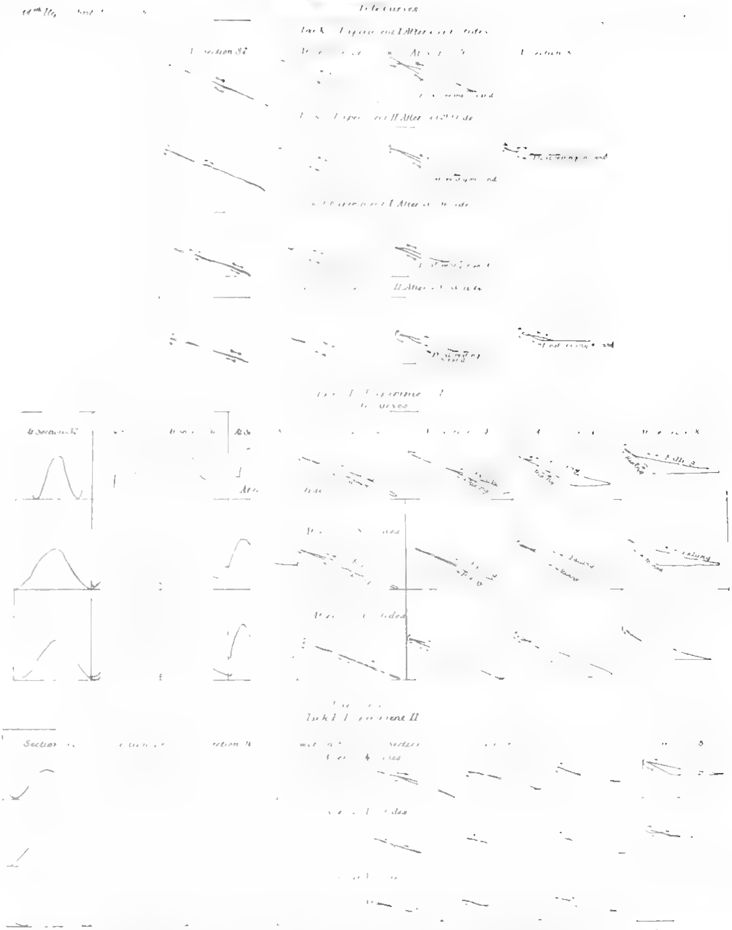
Vertical Scale = $\frac{3}{1}$ (the Model = $\frac{1}{294}$ of an Estuary having a 30 ft tide)

Illustrating the Report of the Committee for investigating the action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models.

Spottiswoode & Co. Lith. London



Illustrating the Report of the Committee for investigating the action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models.



Illustrating the Report of the Committee for investigating the action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models

Report of the Committee, consisting of Dr. GARSON (*Chairman*), Mr. J. THEODORE BENT (*Secretary*), Messrs. H. W. BATES, BLOXAM, *and* J. STUART GLENNIE, Sir FREDERIC GOLDSMID, *and* Messrs. PENGELLY *and* RUDLER, *appointed for the purpose of investigating the Geography and the Habits, Customs, and Physical Characters of the Nomad Tribes of Asia Minor and Northern Persia, and to excavate on sites of ancient occupation.*

THE Committee have to report that during the past year they have had the advantage of the services of the Secretary, Mr. Bent, in carrying out the objects for which they were appointed. The results of the researches of Mr. and Mrs. Bent have been drawn up by them, and the Committee consider it desirable to adopt and reproduce the report as submitted to them by the authors.

The whole of the money voted by the Association at its meeting at Newcastle last year has been expended.

The Committee ask to be reappointed, and that a sum of 30*l.* be placed at their disposal.

Report to the Committee. By Mr. J. THEODORE BENT.

That corner of Asia Minor which constitutes the ancient country of the two Cilicias, mountainous or rugged Cilicia, and Cilicia of the plain, is one of the best points in the world for comparative ethnological study. The great plain, which runs up into the heart of the Taurus Mountains, is in winter scattered over with nomads from the highlands, who erect on it their reed or wicker huts, or dwell in tents until the warm weather drives them up again in search of pasture in the spring. There are Circassians, Kourds, Turcomans, Bosdans, and Afshars, all with their different customs and peculiarities.

Not actually on, but in, the valleys of the mountain, and by the coast where the mountains jut out into the sea south-west of Mersina, you find countless encampments of Yourouks, so called from the Turkish word Youroumek, to wander, descendants of the first nomads, who overran Asia Minor after the fall of the Byzantine Empire.

Again, around Tarsus and Mersina there exist numerous colonies of refugees from distant parts of the world. Sepoys from India, Afghans and Abyssinians; and, lastly, there is a large colony of Ansairee from the Lebanon, who speak Arabic, and are known by the Arabic appellative, *fellaheen.*

Last winter and spring we spent several months amongst the Yourouks of the mountains and the heterogeneous mass of nationalities on the plain, and in so doing, by perpetual contact with them, were able to amass a vast amount of anthropological material. We dwelt in their tents, in ruins, and in tombs, when nothing better presented itself, so as to better acquaint ourselves with the peculiarities of these primitive wanderers.

First of all I will speak of the Yourouks of the mountains, who are found on the southern slopes of the Taurus, or Bulghar dagh, in their tents whenever a little clearing offers a means of subsistence for their flocks. Some of them have adopted a semi-sedentary life for three months of the year, dwelling in hovels erected out of ancient ruins, in the tombs of the ancient Greeks and in other ruins, but as soon as spring comes their abodes become uninhabitable from vermin, and they betake themselves again to their tents. They are an exceedingly peaceful and law-abiding race, a great contrast to their neighbours the Afshars, Kourds, and Circassians, whose habitat is more to the east, and the Turks look upon them as the policemen of the mountains, for they are always ready to give information concerning the thefts and smuggling of the less peaceful tribes, several instances of which came under our notice.

The natural abode of the Yourouk is his black goat's-hair tent, with the camel pack-saddles built round for a wall and the family mattresses spread in the midst; his life is occupied in looking after his flocks, and according to the season he moves from one pasture to another; there are also Yourouk tribes who occupy themselves in wood-cutting and charcoal-burning, and carry on their business with merchants on the coast by an elaborate system of tallies, but they are not so numerous as the purely pastoral tribes.

Their year they divide into three seasons—namely, *Yas*, spring, five months; *Gus*, summer, four months; and winter, three months, which they again subdivide into three parts: (1) *Kampsin*, fifty days; (2) *Karadès*, black winter, ten days; and (3) one month, March, *Zembrai*, or the opening.

They are a fine, active race, insensible to fatigue and hardship, tall and strong, with open countenances, usually dark hair, but lighter complexions than most other tribes in Asia Minor. They dress in loose cotton clothes, and their women do not veil their faces. Their infants they swaddle, first binding round the child's body a rag containing earth heated with a stone; but infant mortality is enormous amongst them. Nearly every woman has a large family, of which only two or three survive. Hence the survival of the fittest and the healthy lives they lead contribute to the fineness of the race. We found a considerable percentage of idiots amongst them, whom they treat with superstitious care; and many instances of abortion in the shape of infants without arms, a wrong number of fingers, &c. One man, from the village of Tapan, north of Sis, had a horn like a goat's horn growing on his head. He is, I hear, coming to Europe to exhibit himself.

Diseases are uncommon amongst them except *teletmeh*, or throat disease, to cure which they wrap the patient in the warm skins of newly slaughtered animals, and disease of the spleen, which they treat with poultices and decoctions of mountain herbs.

Their intercourse with the outer world is very limited; often a well-to-do citizen of some town furnishes a body of Yourouks with flocks by contract; the Yourouk to provide so many okes of milk, cheese, butter, &c., whilst the tribes get what milk is over, the hair, &c., and the contractor agrees also to keep up the flock, if by chance it diminishes. This is termed 'an immortal contract.' In this way the Yourouks often amass flocks of their own, and in time pay off the lender.

These nomads are very destructive to the country they travel over: lighting their fires beneath trees, they ruthlessly destroy acres of timber—and the valleys of this part of the Taurus are rich in tall, straight fir-trees used for masts; then they lay bare whole tracts of country, that they may have fodder for their flocks, and nothing is so destructive to timber as the habit they have of tapping the fir-trees near the root for the turpentine. A deep notch is cut, and the turpentine all flows to this part. After a while the tree is cut down, and the wood in the vicinity of the notch is used for torches, the only light they make use of. Again, they bark the cedars to make their beehives, and for roofing purposes, and are the most destructive enemy the forests of Asia Minor have. Luckily, the vast extent of forest and the sparsity of inhabitants make the destruction of timber less marked; but it is a steady destruction if slow, and must in the end ruin the forests of the country.

In his mountain wanderings the Yourouk has regular visitors at stated times. The goat and sheep merchant comes in the spring, pitches his tent in a central place, sits with the big men of the tribe around him on cushions, smokes his narghili, and has a pot of coffee boiling in the embers, and buys from those who are willing to sell. When he has amassed as many as he can conveniently manage, he sets off to the nearest town to realise a large profit.

They are great camel-breeders, and produce the valuable sort of mule camel common to Asia Minor, and known as the Toulou camel, a cross between the Bactrian and the Syrian; and in spring large Bactrian stallions are brought round amongst the encampments. This cross produces a camel excellent for mountaineering purposes, alike impervious to the snows of the mountains and the heat of the plains.

Then the tax collector comes to gather in the Ashr, or tax on their cattle: he also pitches his tent, and is surrounded by the leading men; but as often as not he has a lot of trouble, for when they are advised of his advent the Yourouks hide a portion of their flocks in out-of-the-way caves to avoid the tax. Then comes the travelling tinker—the great importer of external gossip amongst them—to mend their copper pots; he settles for a few days at each place where he finds ten or more tents, with his bellows and his assistant, and mends with nitre the quaint-shaped coffee-pots and household copper utensils which they use, in return for which he gets butter and cheese, and with these he returns to the town as soon as he has got together as much as his mule can carry. Visits are also periodically expected from the wool merchants, skin dealers, and the public circumciser, who initiates the young Yourouks into the first mysteries of the Mohammedan faith.

In food the Yourouks are exceedingly frugal—their bread in times of plenty is made of flour, in times of famine of acorns; it is of the oatcake type, and baked with great dexterity by women on copper platters over a few embers—cakes with vegetable inside, milk cheese, and very rarely meat, and no wine. Coffee, however, is essential to them, and often I had wondered what these nomads, so unchanged in everything else, did before coffee was made known, until one day when coffee ran short an excellent substitute was provided for us, made of the seeds of a fine species of thistle, botanically termed *Gundelia Tournefortia*, for it was discovered by Gundelscheimer and Tournefort, who calls it the 'finest plant in the whole Levant,' though he apparently was not aware of its use. It grows in dry stony places all over the southern slopes of the Taurus, and is, I understand, very plentiful in Afghanistan. The coffee produced by it is a little lighter in colour, but more aromatic and bitter than ours; they use it also as a stomachic.

By boiling the cones of the *Juniperus drupacea* in a large cauldron for a long time, a thick, sweet stuff is produced; this they mix with flour, and the result is not unlike chocolate cream: they call it *pelteh*.

In producing material from the mountain herbs the Yourouks are very cunning. Before aniline dyes were invented they drove a good trade in colours, but now it does not pay them to continue making them, and European dyes are used by their women in making the Karamanian carpets. The milk of a spurge, called *Galaxidhi* by the Greeks, is boiled with onion-leaves. When the wool is put in, the colour does not at first appear until it is plunged into cold water, when a brilliant red is the result. From the gall of the *Quercus infectoria* they make another dye—in fact, their mountains are covered with herbs useful for all kinds of purposes.

The Yourouks will do anything for tobacco. When it is not forthcoming they make use of certain leaves known to them, and are even known at times to use smoke-dried fig-leaves.

The Yourouks are an exceedingly polygamous race. Poor though he is, a man will often have seven wives, or, more properly speaking, seven slaves. Each wife generally occupies a different tent: one attends to a portion of the flock in one part, another in another direction, another wife looks after the camels, another stays at home to weave carpets, another collects wood and fetches water: and he must be a very poor man indeed who cannot boast of at least three wives. The natural result of this is that the female population, though in excess of the male, is not enough to meet the demand, so that much is done in the way of woman stealing, and if report speaks truly, a Yourouk who wants a wife is not particular in appropriating a married woman from another tribe.

On marriage the husband generally pays something to the father, and this has given rise to the idea that the nomads are in the habit of selling their wives for the harems of Constantinople, whereas they are only carrying out their legitimate idea of the marriage contract. The Yourouks are, strictly speaking, endogamists as far as they can manage it, only going outside when necessity obliges them. In this they are a marked contrast to their neighbours the Circassians, who generally seek a wife from a remote settlement. The Circassians also pay something down for a wife. The *kalim*, or price, is fixed in *baitals*, or mares, their ordinary scale of measurement: 1 camel = 5 mares, 20 sheep = 1 mare, &c. At a betrothal the Yourouks kill a lamb, play the tambourine, let off guns, &c., and exchange handkerchiefs—nothing else. The marriage is a little gayer—dancing and feasting for three or four days; but the ceremony so often repeated seems to lose its zest.

The Turkish Government is anxious to get the Yourouks to settle in some of the more favourable localities on the southern slopes of the Taurus, where a few wretched hovels have been erected, but the Yourouks resent the idea, and doggedly refuse to have a mosque or a Hodja. We saw several attempts to thus bind them; but they resent the idea, and the mosque falls into ruins. Their religion is a truly pastoral one. Sacred trees by the side of the pathways are hung with rags to cure fever, wooden spoons, &c., and there is a little pile of stones hard by which passers-by add to; and when a Yourouk dies, they bring his body to one of these open-air temples, read a little over it from the Koran, and take a few of the small stones to put over his lonely grave. They prefer to bury near a path, so that the passer-by may say a prayer, and this has given rise to the erroneous belief that their cemeteries are those of villages which have disappeared.

Their superstitions are few; they have their Piri, who inhabit streams and houses and cliffs like all savage races, but they believe in nothing that harms them, and have no special dread of ruins. In the mountains where rain-water has settled they say that if a wild animal—an ibex or a bear—has drunk there, and a man from civilisation drinks after it, he will become wild like they are, and this is how they became Yourouks. Where the Yourouk is sedentary and produces crops his tools are of the most primitive nature: the threshing-machine of pine wood, set with flint stones at the bottom fixed along the grain of the wood—cf. Isaiah xli. 15: 'The new sharp threshing instrument having teeth.' On this the man sits and is dragged by bullocks round and round. Their spade is the old Roman bipalium, and their sheep are the fat-tailed ones such as Herodotus described as being 'one cubit in width' (Herod. iii. § 113), and such as one sees on the bas-reliefs of Persepolis. Their churns are skins hung on three sticks, and stirred with a dasher. Wooden utensils are the most generally in use, a wooden mortar for pounding coffee, wooden dishes, bowls, &c.; but then each tent has its heirlooms of copper utensils, which are mended with great care and handed down for generations.

The Yourouks are believers in magic, and have prophets among them, who look in water, open books, and from the grain of wood can tell who has stolen a goat and where it is. The evil eye, too, they strongly believe in, and the efficacy of an onion hung up in the tent to keep it off. Their games are mostly rough, and consist of wrestling and feats of strength.

Yourouk women often mark their bread with the sign of the cross, having seen Christian women doing so, and believe it brings good luck.

They cut the ears of goats, camels, and cows, so that each may know his own cattle by its mark, and some of the marks have a very grotesque effect.

It is difficult to obtain from their tradition any idea of the origin of the Yourouks. They will always tell you that they are the descendants of those who inhabited the ruins amongst which they now dwell, and that their kind ancestors put up letters on the walls to inform them concerning treasure they had concealed. I have seen a Yourouk hard at work with a chisel making his way into a column in which he is sure gold is hidden. I have seen them dig holes below Greek inscriptions with the same object in view.

Each tribe has its Agha, or chief, who is held responsible by the Government for the good conduct of the tribe. Practically he is their legislator, and settles all disputes, for a Yourouk never thinks of taking his grievances before the Turkish law courts.

The advent of the Yourouks into Asia Minor and their origin is lost in obscurity. Bertrandon de la Broquière tells us how two waves of them spread over Asia Minor in the fifteenth century, the first settling in the towns and blending with the Turks, the second preferring to keep up the nomad habits of their forefathers. The great number of Persian words in the dialect of Turkish that they speak—words never used by other Turks, such as *beruh*, 'be off,' *shuma* for 'you,' *pool* for 'money,' &c.—stamps them as originally having used that language and coming from the Persian mountains. In features and colour they are more akin to the Kourds than the Persians or the Armenians. Their skin is fairer, and their cast of countenance would argue that they are of northern origin, perhaps from the mountainous district east of the Caspian.

The physical nature of the country they inhabit to the south of the

Taurus is wild and romantic in the extreme. Deep gorges cut the slopes of the mountains, through which streams find their way to the sea through cliffs of calcareous limestone, sometimes 2,000 feet high—a district rich in deposits of the Miocene period, often full of fossils. Then there are the great caves, or rather depressions, caused by the action of underground streams, known in Asia Minor by the name of *dudens*. The best known of these is the anciently famed Corycian cave, which we thoroughly investigated, and added a large number of inscriptions which had been previously unknown. Adjoining this is a cave of the same nature, called Purgatory by the nomads, into which no one can descend, as the sides slope inwards. Five miles from these is the Olbian cave, three-quarters of a mile round and 200 feet deep.

This country was in ancient days called Olba, and was ruled over by priest-kings of the Teucrid dynasty, as Strabo tells us. We discovered the capital of Olba at a place called Uzenjaburdj, 5,850 feet above the level of the sea, and many inscriptions which quite agree with Strabo's statement. In ancient Greek days this district was covered with towns and villages. Now it is given up to the nomads, and with difficulty one makes one's way through rocks and brushwood where once the grape grew in abundance, and the wild olives and caroubs are the descendants of the ancient cultivation which made this district one of the most favoured corners of the globe, until the advent of these nomads, who have ruined and devastated it.

Our second point of observation this winter was amongst the Ansairee fellaheen who dwell in and around Tarsus, and who are a branch of the race who dwell in the mountains to the north of Latakieh, and who practise a secret religion which has been a subject of great discussion amongst travellers.

Tarsus forms a particularly favourable point for studying this people, inasmuch as they live here amidst an alien population ready to spy on their mysteries and impart what they know. Some years ago an Ansairee youth named Suleiman abjured his faith and wrote an account of it, which was translated and published by Prof. Salisbury in a number of the American Asiatic Society's Journal. This assisted us much in making our researches.

Last year, when travelling in the mountains of Media, near Lake Urumea, we investigated the religious tenets of a race existing there called by the Persians Ali-Ullah-hi, or people who call God Ali. These people also practise a secret religion, and the results of our inquiries I set forth in my report last summer to the Anthropological Section of the British Association at Newcastle-upon-Tyne.

On studying the Ansairee of Tarsus, we were not a little surprised to find that their religion was precisely the same as that practised by the tribe in the North of Persia, and from this coincidence we were able to make valuable anthropological deductions as to the extent of this religion and the number of its devotees.

First, the village in the mountains of Media, which we visited, and which is the headquarters of the sect of the Ali-Ullah-hi, is called Baba Nazere, and they affirm that a certain individual called Nazere was the founder of their sect. Now the Ansairee of Tarsus, or the Nasaree, as the Arabs call them, claim as the founder of their religion a man who lived early in the eleventh century, who is styled in their books as 'the old man of Nazere,' giving us the reason for the name Baba, or old man, which is placed before the name of the village in Persia, and at once establishing a bond of union between the two religions.

Ali is the name for God, the Allah of the Mussulmans, the God of the Christians, in use amongst both of them; and throughout, when closely examined into, the religions are identical.

These points gave us the somewhat startling fact of the vast extent of this secret religion, which has hitherto been supposed to be more or less confined to the so-called Ansairee mountains of the Lebanon and the adjacent villages, whereas in reality it extends from the shores of the Mediterranean to the Caspian, and may be styled the religion of the nomads who traverse this wild mountain district. Future investigations proved to us that the Afshars also belong to it, the Kizilbash, and many Kourdish tribes, and they are all knit together by one bond of mystic brotherhood of religious belief, and know each other, much as the Freemasons of Europe do, by secret signs.

In Persia the Ali-Ullah-hi outwardly conform to the Shiite sect of the Mohammedans. In Turkey the Ansairee outwardly conform to that of the Sonnee, the only external evidence to the contrary being that they have no mosques and say no prayers, never go to Kerbela or Mecca, and do not keep the fasts. To arrive at a definite knowledge of this religion is exceedingly difficult; the facts which I have gathered are from three sources:—

1. The above-mentioned statement of the renegade Suleiman.

2. Information given me concerning the Ali-Ullah-hi in Persia by people of reliable authority.

3. Personal investigations made this year at Tarsus, and evidence contributed by Greeks, Armenians, and Protestants of that place; and as these three sources of information are thoroughly independent, and on the face of it admit of no collusion, they may be clearly taken as giving satisfactory proof of the mysteries of the religion, its vast extent, and the principal tenets which it inculcates.

The fundamental principle of their mystery is to believe in a god whom they call Ali, a name doubtless chosen as a blind in the first instance to their Mohammedan neighbours. In their forms of prayer they address God in somewhat similar strains to those found in Christian prayer-books—'the Creator of all Things,' 'Lord of Glory,' 'the Seed-burster,' 'the Prince of Bees,' or rather Prince of Angels, for the Ansairee have the idea that bees are angels who visit the earth in this form, and suck the fragrance of earth's sweetest flowers.

They have a special prayer to revile those who say that Ali ever took upon himself the form of man, ate, drank, or was subject to like passions as man; their prayers may be styled invocations rather than supplications.

The Ansairee or Nasaree, though admitting as a body the same basis of religious belief, are divided into four sects:—

1. The Northerners or Shemali, a name derived from the Arabic *Shems*, the sun, who say that God, or Ali, dwells in the sun. To this sect belong the Ali-Ullah-hi of Northern Persia; their *ziarets*, or sacred places, are all set up on hill-tops, and the origin of this may possibly be traced to the existence of sun-worship in those parts in ancient days. The Shemali are great fire-eaters, and on the sacred tombs of their departed Seids they say the holy light of Ali comes down much as the Zoroastrians used to say of their fire-temples in olden days.

2. The second sect are called the *Kalazians*, or moon-worshippers—

that is to say, they believe that Ali dwells in the moon, which he created as a palace for himself, and the dark spots thereon resemble him, they say, with the crown on his head and the sword by his side. Most of the Ansairee dwelling around Mersina and Tarsus belong to this sect, and we had ample opportunities of verifying for ourselves the respect they pay to the moon. At full moon they go out and worship to the sound of tambourines, and make a great noise. And again, when the new moon first appears, they prostrate themselves before it. When they pray the Kalazians make the sign of the crescent with their thumb and first finger.

3. The third sect of the Ansairee say that Ali dwells in the twilight, and at that period of the day, the hour of prayer, he pervades the whole heaven.

4. The fourth sect say that he dwells in the air and is for ever present; but of these two latter sects I have had no personal experience, and presume they are only to be met with in the Ansairee mountains of Syria.

The next point of interest, and the one which appears more than anything else to connect them with Christianity, is the Ansairee Trinity. Dr. Wolff and other Orientalists have tried to prove that they have really a Christianity of a decayed form, but from my own investigations I should rather believe that what we find of Christianity amongst them was borrowed and incorporated by the early founders. We have traces of Judaism, Mohammedanism, and sun-worship also in large numbers, and I cannot see that Christianity has any special right to claim them for itself.

Ali is the Father, Mohammed the Son, and Salman el Farsi, abbreviated to Sin, the Holy Ghost. Ali became man, they say, not in his own person, but through his veil Mohammed, and Mohammed when he returned to heaven appointed Salman to superintend the affairs of this world. This Trinity is known amongst them as the mystery of the Ain, Min, Sin, from the three initial letters of the Trinity, A. M. S. By this mystery the novice at his initiation is always made to swear and to repeat the words Ain, Min, Sin over 500 times. Salman is supposed to have superintended the creation of the world, and to have made five incomparables to assist him in regulating the affairs of men.

Bar Hebræus tells us that the old man of Nazere was an inhabitant of the village of Nazaria, in Arabia; he is somewhat cast into the shade as the founder of the religion by one Al Khusaibi, who is said to have perfected it, and to have formed the prayers as they are now used. He taught that all great men and prophets in all ages, leaders of men in fact, are incarnations of Ali—a subtle way, common also to Mohammedans, of trying to introduce the cream of several religions into their own. In this list we find Plato, Socrates, Alexander the Great, Jesus Christ, Mohammed the founder of Islamism, and many others; whereas celebrated women, the wives of these great men, with the exception of Noah's and Lot's wives, are said to be incarnations of Salman el Farsi.

From the surrounding religions they have borrowed their festivals and religious observances, and arguing from this Dr. Wolff has gone as far as to say that Nazere is derived from Nazareth, and that the errors only crept in when Al Khusaibi recognised the religion; but this is mere speculation, and I think it much more likely that he strove to embrace in his cult all that he thought expedient from all parties.

The cup of wine common in all their feasts may be said to be of distinctly Christian origin: 'the image of Ali,' as they call it, is passed round and partaken of by each of the guests; first the Seid, or priest, drinks some and hands it to his right-hand neighbour, who kisses his hand and passes it on: whereas a distinct trace of Judaism is found in the Persian mountains—a sheep without blemish is roasted without its hoofs and horns, and the Seid distributes the meat in portions to the assembled worshippers; but I could not find that this was done at the Ansairee feasts in the Cilician plain. Some say, whether from this cause I know not, that the Ansairee are Canaanites, descendants of those whom the children of Israel cast out of Palestine; but I do not see any foundation for this theory.

With the Christians the Ansairee observe Epiphany, the feast of St. John the Baptist, the feast of Mary Magdalene, Good Friday, and Christmas. One of their prayers for Christmas Eve, the feast of Melad as they call it, is very curious: 'Thou didst manifest in that night thy name, which is thy soul, thy veil, thy throne to all creatures as a child, and under human form'; but whilst they do not believe in the Crucifixion, but say that Ali took up Eesa to himself, as they call Jesus, they will at the same time go to the Greek church at Tarsus on Good Friday, and, like the Greeks, pass under the representation of the Entombment, appearing to derive physical good from so doing.

Epiphany is called by them the feast of Yetas, and on this day the Ansairee of Tarsus go in parties to the banks of the river Cydnus, perform their ablutions, and wash their clothes.

Some of their prayers to or invocations of Ali are really very beautiful, and great solemnity is a feature in their worship, silence being always observed 'over the myrtle,' as they term their services, from the myrtle boughs which are spread for them to sit upon. Sometimes before the Sheikh or Seid a bowl of water is placed, and olive-twigs are put inside. Afterwards these are distributed to the people, who stick them in their gardens and beehives for good luck. From a Greek of Tarsus, who professed to have been eye-witness of one of their services from a lemon-tree in a remote garden, I had evidence confirming the use of the myrtle amongst them as a sacred plant. It is very plentiful in this locality, and the name of the town, Mersina, is derived from it.

At Tarsus the Ansairee are all gardeners, and own most of the productive gardens filled with oranges, lemons, and pomegranates, which surround the city; their love of flowers is excessive. Ansairee women, who go about unveiled, wear an extravagant number of flowers in their hair, and at an Ansairee wedding I witnessed the display of flowers was magnificent; the women dance publicly before men, a thing which greatly scandalises the Turks, who would not so much as touch a piece of meat which had been killed by an Ansairee. Their Sheikh goes once a week to the Mosque for appearance sake.

Sheikh Hassan is the chief of the Kalazians at Tarsus, and one of the richest men in the place; he has a fine open countenance, ruddy complexion, and long grey beard; he told me that he came to Tarsus with others of his race from the Lebanon about fifty years ago, probably the time of the first Ansairee colony in Cilicia; they were poor, and came in search of work, but now by their industry they have got most of the good land of Tarsus into their own hands, and they are reported to be 10,000 strong. Be this as it may, they practically govern the town, and dictate to the Turkish governor what terms they please. Many entire villages on the plains belong to them, and as they are most of them Kalazians, Sheikh Hassan is a man of considerable importance. He receives tithes from the people, and lives in one of the best houses on the outskirts of the town. He has a reputation for great generosity, as he feeds 150 poor at his own expense every Friday. He is one of those who, they say, will at once become stars when they die, without going through any of those unpleasant transformations which are a common fact of their belief. With them metempsychosis partakes strongly of the ridiculous: bad men put on 'low envelopes,' or Kamees, in the next world; Mussulmans become jackals, and Jewish Rabbis apes; a man may be punished by becoming a woman, but a good woman may be rewarded in the next life by becoming a man; and many kindred ideas of this nature.

Lastly, I will say a few words about the mystery of initiation into the Ansairee faith—El Kudda, as they call it. Only males are initiated, and not till they are sixteen or thereabouts. The admission is only done by degrees; only after the lapse of various probationary periods, sometimes never at all, the final mysteries are revealed. The cup of wine is present, as at all their festivals, and the sandal of the Seid or Sheikh is bound on to the head of the novice with a white rag. The novice has to have no less than twelve sponsors, who promise to cut him in pieces if he discloses anything, and it is commonly reported at Tarsus, with what amount of truth I know not, that the tongues of two men who revealed secrets are kept in pickle and shown at the initiation as an awful warning to the youth. For the twelve sponsors there are to be two other sponsors, who are answerable for the good conduct of the twelve, and the oath by the mystery of the Ain Min Sin is administered, the novice repeating the same 500 times.

The various probationary periods are forty days, and then seven months, by which time the novice is supposed to have had time to learn the sixteen prayers to Ali, and to be sufficiently prepared to become an ordinary member of their body. What length of time it takes before the youth is admitted into the higher degrees I do not know. Altogether their system of secrecy is very like that of the Freemasons. By a shake of the hand an Ansairee will know his co-religionist, whether he dwells on the shores of the Caspian or the Mediterranean, and they have kept their secret well, quite as well as the masonic bodies of Western Europe.

Our further investigations into the nomad tribes of this district were to the north-east of the Cilician plain, where vast tracts of uncultivated country are given up to them and their flocks, a country capable of great development if only a settled government could give security to the farmer; as it is, nearly every attempt at farming has failed. Near Adana I was told of a farm with house and stock which could be bought for 150*l*., but then there had been three years of famine, and the landowners were at their wits' end to pay their taxes and their wages.

Our first intercourse with the Afshars of the Cilician plain was near the rock fortress of Anazarba, where a detachment of them have taken up their winter quarters. The Afshars are a very numerously divided scattered tribe, chiefly of nomadic tendency. We saw a good deal of them in Northern Persia, where they are said to have aspired to the throne, and the great Shah Abbas of Persia, to counteract their influence, established the tribe of the Shah Sevan.

In Persia the Afshars would appear to be of Kourdish origin, from their names and propensities. The Afshars to the south are much mixed up with the Armenians, having old Armenian words in their dialect of Turkish, and names of a distinct Armenian provenance. In Persia they talk Tatar-Turkish, but to the south their dialect is little different from that of the other nomads amongst whom they live.

The Afshars, who were encamped just inside the ruined walls of Anazarba, build themselves wicker huts made very dexterously out of the reeds which grow in the neighbouring marshes; most of them consist of two rooms, with a partition in the middle for the calves; the floors are of mud, and in wet weather, as it unfortunately was during most of our time there, these tenements are exceedingly disagreeable. In spring-time, when they go up to the mountains with their cattle, they set fire to these huts and rebuild them again the following winter.

One of the most notable points about these nomads are the magnificent dogs they possess—huge animals resembling St. Bernards and intensely savage. During our stay we never dared to go out alone, without one of the tribe, man, woman, or child, to protect us. They feed them on butter-milk poured into holes in the ground, and at night-time they are trained to prowl about and patrol the encampment at a certain distance, so as to give ample warning of the approach of an enemy; for in this part of Cilicia there are many robbers from the Kourdish and Circassian tribes. They cut their ears short, so that they may hear better, and they are exceedingly attached to them. 'Better shoot one of their children than one of their dogs,' I was warned when threatening to shoot one if attacked. The nights we spent in these huts were miserable; it would seem that the Afshars never sleep, and all night long they were watching their cattle, driving them from the reed houses, which they tried to eat, and no peace of any sort could be got. At early dawn the noise of the churning began, and quiet only appeared to reign during the absence of the flocks at their pasturage.

The Afshar is very different from a Yourouk; he is not so tall or well built, he is swarthy, has a round and often hairless face, and small, narrow eyes; a face which often reminded us of the Chinese type, and it would seem that he has come from far in the heart of Asia.

The women are fat and stumpy: they wear down their backs long plaits of false hair, which they make out of cotton or silk, and then dye to suit the colour of their own hair; on to this they fasten odds and ends of silver ornaments, and they call them *ourmeh*. Their faces are always unveiled, except a bride, who conceals her face for the space of a year, and most of them have their noses bored; into the hole they put a clove, which puzzled us for a long time, for it resembled a nail—the idea being, I imagine, to sweeten the breath. They wear red drawers, go about with their feet always bare, and have embroidered jackets. Modesty seems to be a thing unknown amongst them; several times we saw women stark naked by a stream washing themselves and their clothes, and the presence of men in the vicinity did not appear to disconcert them in the least.

For fuel they use nothing but the reeds from the neighbouring marsh, which they put damp on to their fires, and they go off like a fire of musketry, rather alarming us at first at night-time, when we never felt sure that a body of Circassian robbers was not upon us. In other encampments we found them using *tezek*, or dung cakes, for fuel, in making which the women are principally employed.

For water they use curious large wooden *amphoræ*, hollowed out of the trunks of trees and elegantly carved; out of trunks of trees they make their beehives too, blocking up the ends with cakes of dung. Their bees they always take with them to the mountains, and they boil the wax and honey together, making cakes resembling soap, which they eat.

The men of some of these tribes wear very pretty loose blue jackets embroidered with gold, and carry narrow-handled guns beautifully chased, and with the barrel decorated with six or seven bands of silver.

The Bosdans, or followers of Bosadan Oglon, are another tribe, but of distinctly the same origin as the Afshars, and, I imagine, come from the same stock. Their women wear the same costume, only that they have large, circular, gold ornaments at each ear, and are altogether more lavish in the number of ornaments which they contrive to fasten on to the ourmeh, or false plait, which hangs down their back.

The women of these tribes are great workers, and produce a great number of the *gelims*, or coarse carpets, inferior indeed to the Karamanian carpets made by the Yourouks, but very effective when the patterns are elaborate and the colours well blended; in every wicker house is the loom, with holes in the ground where the legs of the woman at work disappear to work the pedals. By the Jeihan, the ancient Pyramus, the tribes have great quantities of buffaloes and rude carts, with large round wheels, made out of one piece of wood, with the axle passed through.

At Hemita-kaleh the resemblance to Chinese was very marked. A man without his fez, with the front part of his hair shaved close, and left to grow long behind, with his yellow skin, high cheek bones, and almond-shaped eyes, would pass very well for an inhabitant of the Celestial Empire. Many of these Afshars claim to reach a great age. We were shown one who said he was 121, and could walk well; the only point, however, which is certain is that longevity is common amongst them.

At Bodroum our home again was a hovel built out of wattled bamboos, and covered on the inside with pats of manure, which they whitewash and decorate with rude patterns in henna. Here, again, they are Afshars, but the women wear a different costume—red leather shoes to keep off the snakes, red baggy trousers, blue skirt, and red satin jacket, a fez bound round with lace, and splendid gold ornaments at each ear, and a frontlet of coins.

At Bodroum are the extensive ruins of an ancient city, on a slope about three-quarters of a mile from the Pyramus. These ruins are full of nomads; one family lives in the ancient theatre, another in an ancient Christian church, another has taken possession of a tomb; and woe to anybody who wanders about unprotected—the dogs of the place are perfect demons. Appellatives are given to individuals, such as 'the broken hand,' 'the lame man,' from misfortunes that have happened to them. The owner of the theatre had had his leg and right arm damaged in a struggle with a leopard, and hence gained his distinguishing name.

On the banks of the Pyramus they have fine fields of grain; when reaped and threshed they bury the grain in holes in the ground, cover it with straw, bushes, and earth, and keep it thus till wanted. This is a very ancient custom, common in classical days, when these holes in the ground were called *σιροί*. Our investigations at Bodroum eventually resulted in our discovering from several inscriptions that the ancient name of the place was Hieropolis Castabala. Strabo gives an account of the priestesses of Artemis Perasia, who here walked over burning coals unhurt. Many commentators have tried to argue that for Perasia should be read Persica, but we discovered two inscriptions with the word Perasia thereon, distinctly proving that Strabo was right.

Furthermore, by the identification of this site, the route Alexander the Great took before the battle of Issos is more clearly demonstrated. From the coast line he went inland to Castabala, sent Parmenio to reconnoitre the pass through which the main road to Syria then passed, and when he had made sure of the ground behind him he dropped down to the coast again, which is about twenty miles distant, keeping the Amanus mountains to his left. Hitherto travellers have sought for Castabala down by the coast, but the identification of our site by epigraphy leaves no room for doubt that this was the point to which Alexander made.

Report of the Committee, consisting of Sir WILLIAM TURNER, Mr. BLOXAM, Professor FLOWER, Dr. E. B. TYLOR, *and* Mr. RISLEY, *appointed to investigate the Habits, Customs, Physical Characteristics, and Religions of the Natives of India.*

PREPARATIONS have been made for carrying on the work of the Committee during the ensuing year, when Mr. Risley will have returned to India. A series of questions specially applicable to the natives of India is being drawn up, and the Committee anticipate valuable results from the replies that will be received from the officials and others amongst whom these questions will be circulated.

The Committee ask for reappointment, and that the grant of 10*l.*, which was made last year in view of possible preliminary expenses but has not been drawn, may be renewed.

Report of the Committee, consisting of General PITT-RIVERS, *Chairman*, Dr. GARSON, *Secretary, and* Dr. BEDDOE, Professor FLOWER, Mr. FRANCIS GALTON, *and* Dr. E. B. TYLOR, *appointed for the purpose of editing a new Edition of 'Anthropological Notes and Queries.'*

THE Committee has to report that during the past year substantial progress has been made with the new edition of 'Anthropological Notes and Queries,' by the Anthropological Institute of Great Britain and Ireland, under the supervision of the council, of which body the work is being done, as stated in the last report. During the present year the medical portion of the work has been entirely reorganised and rewritten by eminent members of the medical profession, and has been printed. The part of the work on physical anthropology has been almost entirely rewritten, and is all but ready for the press. Some delay has been caused by the difficulty of obtaining satisfactory coloured plates for standards of the colour of hair, skin, and eyes. Those in the previous editions, it has been found, lost colour rapidly, even when not exposed to the light. As these standards are necessarily exposed to a considerable extent where the book is in constant use changes take place more rapidly; hence the results obtained from them are liable to be very fallacious. The desirability of obtaining standard colours which are less liable to deteriorate is most important, and it is hoped the difficulties hitherto met with on this score may be overcome. By the end of the present year the Committee expects the work will be in the hands of the public.

Fourth Report of the Committee, consisting of Sir JOHN LUBBOCK, Dr. JOHN EVANS, Professor W. BOYD DAWKINS, Dr. R. MUNRO, Mr. W. PENGELLY, Dr. HENRY HICKS, Professor MELDOLA, Dr. MUIRHEAD, *and* Mr. JAMES W. DAVIS, *appointed for the purpose of ascertaining and recording the localities in the British Islands in which evidences of the existence of Prehistoric Inhabitants of the country are found. (Drawn up by* Mr. JAMES W. DAVIS.)

THE report now presented by your Committee is somewhat brief; it is expected, however, that those interested in the subject—who are preparing reports for the counties of Northumberland, the West Riding of Yorkshire, North Lancashire and Westmoreland, Essex, Hampshire and Dorsetshire, and the northern counties of Ireland—will be prepared to present them for publication at no distant date, and it is hoped that at the next meeting of the Association the report will not only be a more voluminous and important one, but that several additional lists will be in course of preparation in other parts of the country. It is desired to draw the attention of those who have undertaken to record the occurrence of prehistoric objects, or who may do so, to the method suggested in the first report made in 1887, in which it is requested that information be given as to (1) the object, (2) the locality where found, (3) the date when found, (4) state if previously described and where, (5) special characteristics, and (6) where the object is now deposited. In the case of large objects, as caves, earthworks, lake-dwellings, tumuli, dolmens, &c., it has been decided to record them on the 1-inch Ordnance Survey maps, and the signs and colours adopted are given in the second report of the Committee, published in the volume for year 1888.

A list of prehistoric objects found in the parish of Rochdale, prepared by J. Reginald Ashworth, Honorary Secretary of the Rochdale Literary and Scientific Society, has been received by the Committee.

Flint implements and chippings have been found in the neighbourhood of Rochdale at:—

Blackstone Edge
Brandwood Moor
Brown Wardle Hill
Cow Heys, } Haugh
Crow Knoll, } Haugh
Culvert Clough, Bleakedgate-cum-Roughbank
Flower Scar Hill, Todmorden
Foxton Edge, Bleakedgate-cum-Roughbank
Hades Hill, Huddersfield
Helpit Edge, Haugh
Hunger Hill, } Catley Lane
Knoll Hill, } Catley Lane
Longden End Moor, Lowhouse
Lower Moor, Todmorden
Middle Hill, Wardle
Ramsden, Walsden
Robin Hood's Bed
Rough Hill, } Wardle
Rushy Hill, } Wardle
Tooter Hill, } Brandwood
Trough Edge, } Brandwood
Turnshaw Hill, Catley Lane
Wardle
Wardle Moor
Well 'ith' Lane

The flint objects are generally discovered on the neolithic floor, found about 1,300 feet above sea-level, and covered with a layer of peat varying from 1 to 10 feet in thickness. They consist of knives, scrapers, arrow heads, spear tips, and very small implements, possibly for boring eyes in bone needles, all unpolished.

The list has been extracted principally from the recently published 'History of Rochdale,' by Lieut.-Col. Fishwick.

Dr. H. C. Marsh has found fragments of hæmatite and graphite on Knoll Hill (one of the localities where flints have been discovered), which may have been used as pigments.

Four years ago some tumuli at Worsthorn and Extwisle, near Burnley, were investigated, and a cinerary urn was disinterred from one of them. It is 12 inches in height and $10\frac{1}{2}$ inches in diameter, made of unbaked clay, and pre-Roman in character. The urn contained the charred remains of two bodies; the only artificial object being a bronze pin. Dr. Marsh, who described the urn and its contents, considers that the interment took place during the Bronze Age.

Your Committee request to be reappointed without a grant.

Report of the Committee, consisting of General PITT RIVERS, Dr. GARSON, *and* Mr. BLOXAM, *appointed for the purpose of Calculating the Anthropological Measurements taken at the Newcastle Meeting of the Association in* 1889. (*Drawn up by* Dr. GARSON, *Secretary.*)

THE Committee has to report that the arrangements made by the local committee for the Anthropometric Laboratory in connection with the Anthropological Section at Newcastle last year were most excellent. A large and well-lighted room in the same building as the meeting-room of the Section was set apart for the laboratory, and the services of a clerk were placed at the disposal of the sectional officers. By the kind permission of Mr. Francis Galton, the services of the superintendent of his laboratory at South Kensington—Sergeant Randal—were again available to carry on the work of the laboratory, in conjunction with Mr. Bloxam and Dr. Garson. The new instruments mentioned in last report were used for the first time, and proved fairly satisfactory. With the prospect of an efficient number of instruments available for work in the laboratory, it was decided that the observations made should be of a somewhat more physical character than had been previously the case, and that they should agree as much as possible with the system of observations instituted by Professor Topinard. As the number of hands in the laboratory was limited in proportion to the number of applicants to be measured, it was necessary to select the most important measurements, and those which could be made with the greatest amount of accuracy in the least possible space of time. On this account it was thought desirable to cut out several observations previously made, particularly amongst those relating to the efficiency of some of the organs of sense, which required some time to test accurately.

The list of observations was as follows:—sex, age, birthplace, occupation, colour of eyes and of hair, the height of body when standing with boots or shoes on the feet, and the thickness of the heel; by subtracting the latter the actual stature was determined: the height when sitting and when kneeling with the body in an upright position; the maximum length and breadth of the head, and the cephalic index: the vertical distance or projection from the vertex to the tragus, to the mouth and to the chin respectively; the length and breadth of the nose and nasal index; the length and breadth of the face (the former measured from the nasion to the under surface of the chin, the latter the greatest width between the external surfaces of the zygomata), and the facial index obtained from these measurements; the length of cubit and of middle finger; the space of arms measured across the back; the weight in ordinary walking clothing; the strength of pull with right and left hands, and the strength of pull of a person, being the mean pull of the two hands; the vital capacity of the chest. In males the circumference of the chest during greatest inspiration and during forced expiration were ascertained and the difference recorded. The vision of each eye and the power of distinguishing colour were the only observations made on the efficiency of the senses. As on previous occasions, a duplicate form was provided of these observations, and by means of a sheet of carbon paper a duplicate copy of the measurements was made and handed to each person who submitted to the various tests.

The number of persons measured was 125; of these 81 were males and 44 females. The time occupied in going through the various tests was about a quarter of an hour per person. During the first day the number of members and associates who found their way to the laboratory were small, consequently the number of observations made that day were few. Afterwards, however, the numbers were increased and the attendants and one or other of the secretaries (when the latter was able to leave the duties of the Section room and take part in the laboratory work) were kept very busy. Indeed it was impossible for the staff to measure nearly all who presented themselves for that purpose, notwithstanding that the laboratory was kept open daily from 10 A.M. till 4 P.M. till the close of the meeting.

The work of the laboratory was ample to test the capabilities of the instruments, and although these were, on the whole, very satisfactory for the purposes for which they were intended, yet improvements were suggested by practical experience which would render them more efficient. During the winter these alterations have been carried out. It must be remembered, however, that the funds subscribed were only sufficient to purchase the most necessary instruments in the first instance, and that some more apparatus is still necessary before the laboratory can be considered to be efficiently equipped.

In compiling the results of the observations made in the laboratory last year at Newcastle, the system of centesimal grades introduced by Mr. Francis Galton has been employed, as in the previous report of the laboratory at the Bath Meeting of the Association. This system is found to be less laborious in working, and to give much more information regarding the variations in the series of persons measured. The Committee is also satisfied that the list of measurements adopted last year is a distinct advance on those previously used, in that much more extensive information is gained regarding the physical characters of the persons examined, and the results obtained will be more widely comparable to those made in other countries on other races of mankind, being the same in the most essential elements as have been submitted to anthropologists in France by Professor Topinard, and as are adopted in the new edition of 'Anthropological Notes and Queries' of the Association.

As the Committee considers that valuable statistics are yearly obtained from the Anthropometric Laboratory of the Association regarding the physical characters of the educated classes of the community who live under favourable circumstances as to nourishment and development, it asks to be reappointed, and that such a sum of money be placed at its disposal for carrying on the investigations this year as the Committee of the Anthropological Section may recommend. All the money granted by the Association last year has been expended on printing and working up the following statistical results.

Age.

The age of the persons on whom observations were made is as follows: Males, under 20 years, 10; between 20 and under 30 years, 23; between 30 and under 40 years, 21; between 40 and under 50 years, 8; between 50 and under 60 years, 10; between 60 and under 70 years, 6; between 70 and under 80 years, 3.

Females: under 20 years, 9; between 20 and under 30 years, 12; between 30 and under 40 years, 11; between 40 and under 50 years, 8; between 50 and under 60 years, 3; between 60 and under 70 years, 1.

Birthplace.

Great diversity was found, as might be expected, regarding the birthplace of those examined. There were persons from almost all parts of the United Kingdom, but almost 50 per cent. were born in Newcastle and the country and towns round about it. The next most frequent birthplace was London, where rather more than 14 per cent. were born.

Colour of Eyes and Hair.

The number of males with light eyes and light hair was 44, and of females, 21. With light eyes and dark hair there were 26 males and 13 females. With dark eyes and dark hair there were 8 males and 6 females. Two ladies are noted to have had dark eyes and light hair; this combination was not observed amongst the males.

Height when Standing Erect.

The most accurate method of measuring the stature is doubtless without boots or shoes. To measure in this way was not practicable, so that the method of measuring the person in boots and shoes, and subtracting from the stature so obtained the thickness of the heel, had to be adopted. In the males the actual stature thus obtained varied from 1^{m} 575 to $1^{m}{\cdot}875$, the mid-stature being $1^{m}{\cdot}715$. At the 25th grade it is found to be $1^{m}{\cdot}670$, and at the 75th grade $1^{m}{\cdot}760$; the probable deviation being 45mm. (*i.e.*, half the difference between these two last grades), the corrected mid-stature is $1^{m}{\cdot}715$. In the females the actual stature varied from $1^{m}{\cdot}450$ to $1^{m}{\cdot}775$, the mid-stature being $1^{m}{\cdot}589$. At the 25th grade it is $1^{m}{\cdot}541$, and at the 75th grade $1^{m}{\cdot}627$, the probable deviation between these two last grades being 43mm. The corrected mid-stature of the females is $1^{m} \cdot 584$, which shows a difference of 131mm. less than the males (=about $5\frac{1}{8}$ inches).

Stature in Males.

1575	1600	1625	1650	1675	1700	1725	1750	1775	1800	1825	1850	1875	Stature in mm.
2	1	4	9	11	11	12	10	11	3	3	1	1	Total observations 79
2	3	7	16	27	38	50	60	71	74	77	78	79	Abscissæ 0–79

Stature in Females.

1450	1475	1500	1525	1550	1575	1600	1625	1650	1675	1775	Stature in mm.
1	3	1	4	7	5	7	7	5	2	1	Total observations 43
1	4	5	9	16	21	28	35	40	42	43	Abscissæ 0–43

Each of these divisions progressing by 25mm., they may roughly be taken to represent inches, $1^{m} \cdot 575$ being equivalent to 62 inches, and $1^{m} \cdot 600$ to 63 inches, and so on.

The stature of persons measured at Bath Meeting contained in last year's Laboratory Report are somewhat different, as there we found that the corrected male mid-stature was $1^{m} \cdot 725$, and that of the females $1^{m} \cdot 587$.

LENGTH OF THE BODY WHEN SITTING.

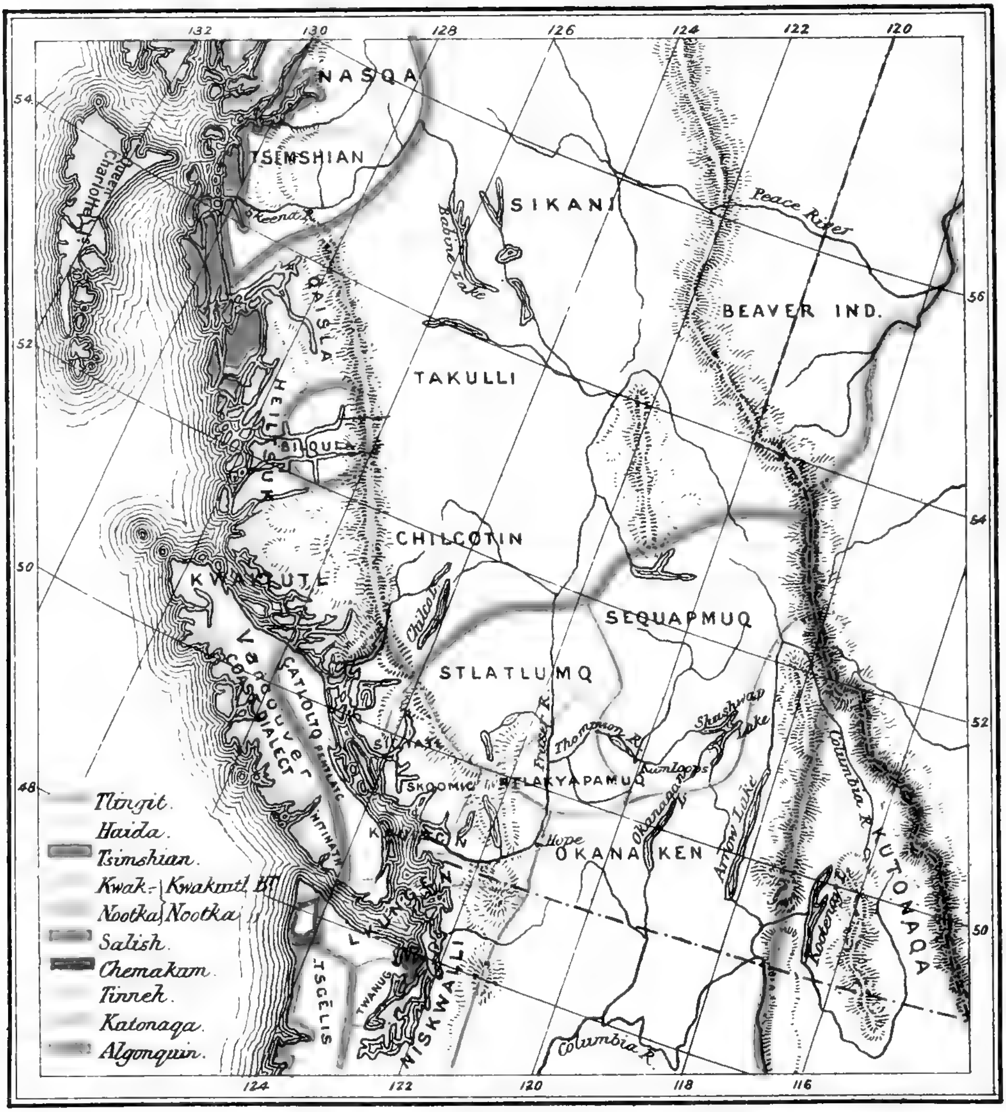
The length of the trunk of the body indicated by the sitting height varies in the males from 800mm. to 960mm., the mid-length being 896mm. At the 25th grade it is 862mm., and at the 75th grade 916mm.: the probable deviation is therefore 27mm., giving a corrected mid-grade of 889mm. In the females this length varies from 790mm. to 910mm., mid-length being 830mm. At the 25th grade it is 803mm., and at the 75th grade 858mm. 27mm. therefore represents the probable deviation, giving a corrected mid-grade of 830mm., or 59mm. less than in the males. In last report the corrected mid-grade of body length was found to be 900mm. in the males, and 847mm. in the females.

Males.

800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	Sitting height
1	2	2	2	3	7	2	2	7	7	8	10	11	5	4	3	3	Total observations 79
1	3	5	7	10	17	19	21	28	35	43	53	64	69	73	76	79	Abscissæ 0–73

Females.

790	800	810	820	830	840	850	860	870	880	890	900	910	Sitting height
1	8	2	3	5	6	3	3	0	4	3	1	2	Total observations 43
1	9	14	16	21	27	30	33	33	37	40	41	42	Abscissæ 0–43



LINGUISTIC MAP OF BRITISH COLUMBIA.

Note.—*The Tinneh are according to Dr. G. M. Dawson. Broad coloured lines denote limits of branches of one linguistic stock, thin coloured lines limits of more closely related dialects.*

Illustrating the Sixth Report on the North-Western Tribes of the Dominion of Canada.

Sixth Report of the Committee, consisting of Dr. E. B. TYLOR, Mr. W. BLOXAM, Sir DANIEL WILSON, Dr. G. M. DAWSON, General Sir H. LEFROY, *and* Mr. R. G. HALIBURTON, *appointed to investigate the physical characters, languages, and industrial and social condition of the North-Western Tribes of the Dominion of Canada.*

[PLATE XIX.]

THE Committee have been able once more to secure the services of Dr. Boas, who has drawn up the bulk of the report on the tribes of British Columbia. This is accompanied by a linguistic map, and preceded by remarks on British Columbian ethnology by Mr. Horatio Hale. The grant made to the Committee was supplemented by 500 dollars from the Canadian Government, and the Committee suggest that each member of the Dominion Parliament should be supplied with one copy of the report. The Committee ask for reappointment, and for a grant of 200*l.*

Remarks on the Ethnology of British Columbia: Introductory to the Second General Report of Dr. Franz Boas on the Indians of that Province. By HORATIO HALE.

A reference to the map annexed to this report will show at a glance those striking characteristics of British Columbian ethnography which were described in my remarks prefixed to the report of 1889.[1] These peculiarities are the great number of linguistic stocks, or families of languages, which are found in this comparatively small territory, and the singular manner in which they are distributed, especially the surprising variety of stocks clustered along the coast, as contrasted with the 'wide sweep' (to use the apt words of Dr. G. M. Dawson) 'of the languages of the interior.' To this may be added the great number of dialects into which some of these stocks are divided. The whole of the interior east of the coast ranges, with a portion of the coast itself, is occupied by tribes belonging to three families—the Tinneh, the Salish (or Selish), and the Kootenay (or Kutonaqa). What is especially notable, moreover, is the fact that, according to the best evidence we possess, all the tribes of these three stocks are intruders, having penetrated into this region from the country east of the Rocky Mountains. In the third report of this Committee (1887) are given the grounds for concluding that the Kootenays formerly resided east of these mountains, and were driven across them by the Blackfoot tribes. In the fourth report

[1] It should be mentioned that this map has, on my suggestion, been framed on the plan of my 'Ethnographic Map of Oregon,' though necessarily on a smaller scale (see vol. vii. of the *United States Exploring Expedition under Wilkes*: 'Ethnography and Philology,' p. 197). The two maps are, in fact, complements of each other. Those who desire to study this subject thoroughly, however, should refer to the valuable maps of Mr. W. H. Dall and of Drs. Tolmie and Dawson, the former appended to the Report of Dr. George Gibbs to the Smithsonian Institution on the 'Tribes of Western Washington and North-Western Oregon,' in vol. i. of *Powell's Contributions to North American Ethnology* (1877), and the latter attached to their *Comparative Vocabularies of the Indian Tribes of British Columbia,* published by the Canadian Government (1884). These maps are on a much larger scale and supply many important details.

(1888) the connection between the Tinneh tribes east and west of the mountains is explained; and in the Smithsonian report of Dr. Gibbs on the West Washington tribes, that accomplished ethnologist has given his reasons for holding that the Salish formerly resided east of the mountains, and have made their way thence to the Pacific, driving before them or absorbing the original inhabitants.[1] To this intrusion and conquest are doubtless due the many Salish dialects, or rather 'dialect-languages,' differing widely in vocabulary and grammar, which have been evolved (like the Romanic languages of Southern Europe or the modern Aryan languages of Hindustan) in the process of this conquest and absorption.

A remarkable evidence is found in the case of the Bilhoola (Bilqula) tribe and language. This tribe, belonging to the Salish family, is wholly isolated from the other septs of that family, being completely surrounded by Kwakiutl tribes and Tinneh, into whose territory it has apparently pushed its way. As a result its speech has undergone so great a change that by some inquirers it was at first supposed to be a totally distinct language. A still more striking instance of a mixed language, though not belonging to the Salish family, is furnished by what is now termed the Kwakiutl-Nootka stock. Until Dr. Boas last year visited the Nootka people and carefully analysed their language, it had been supposed by all investigators, himself included, to be a separate stock, radically distinct from all others. The analysis now furnishes clear evidence of a connection between this idiom and the more widespread Kwakiutl. The connection, however, is so distant, and the differences in vocabulary and grammar are so important, that we are naturally led to suspect here also a conquest and an intermixture. The Nootka tribes who inhabit a portion of the west coast of Vancouver Island, and who were so named from a harbour on that coast, have been more lately styled by good authorities the 'Aht nation' from the syllable *aht* or *ath*, meaning 'people' or 'tribe,' with which all their tribal names terminate—Nitinaht, Toquaht, Hoyaht, Seshaht, Kayoquaht, &c. Their speech, though in certain points resembling the Kwakiutl, has yet, to a large extent, its own grammar and vocabulary. It seems probable that we see in it the case of an originally distinct stock, which at some early period has been overpowered and partially absorbed by another stock (the Kwakiutl), and yet has subsequently pursued its own special course of development. The comparison of the two languages, as now presented by Dr. Boas, offers, therefore, a particularly interesting subject of study.

All the languages of British Columbia of every stock have a peculiar phonology. Their pronunciation is singularly harsh and indistinct. The contrast in this respect between these languages and those immediately south of them is very remarkable and indeed surprising. As the point is one of much interest, I may venture to quote the remarks on this subject with which (in my work before cited) the account of the 'Languages of North-Western America' is prefaced:—

'The languages of the tribes west of the Rocky Mountains may be divided into two classes, which differ very strikingly in their vocal elements and pronunciation. These classes may be denominated the northern and southern, the latter being found chiefly south of the Columbia, and the former, with one or two exceptions, on the north of that river. To the northern belong the Tahkali-Umqua (or Tinneh),

[1] See page 224 of the report referred to in the preceding note.

the Salish, the Chinook, and the Iakon languages, with all on the north-west coast of which we have any knowledge. The southern division comprehends the Sahaptin, the Shoshoni, the Kalapuya, Shaste, Lutuami, and all the Californian idioms so far as we are acquainted with them. Those of the northern class are remarkable for their extraordinary harshness, which in some is so great as almost to surpass belief. The Chinooks, Chikailish, and Killamuks appear actually to labour in speaking; an illusion which proceeds no doubt from the effect produced on the ear of the listener by the harsh elements with which their languages abound, as well as the generally rough and dissonant style of pronunciation. The χ is in these tongues a somewhat deeper guttural than the Spanish *jota*. The *q* is an extraordinary sound, resembling the hawking noise produced by an effort to expel phlegm from the throat. $T\chi l$ is a combination uttered by forcing out the breath at the side of the mouth between the tongue and the palate. These languages are all indistinct as well as harsh. The same element in the Chinook and other tongues is heard at one time as a *v*, at another as a *b*, and again as an *m*, the latter being probably the most accurate representation. Similarly the *n* and *d* are in several dialects indistinguishable, and we were constantly in doubt whether certain short vowels should be written or omitted.

'The southern languages are, on the other hand, no less distinguished for softness and harmony. The gutturals are found in two or three, into which they seem to have been introduced by communication with the northern tribes. The rest want this class of letters, and have in their place the labial *f*, the liquid *r*, and the nasal *ñ* (ng), all of which are unknown to the former. Difficult combinations of consonants rarely occur, and the many vowels make the pronunciation clear and sonorous. There is, however, a good deal of variety in this respect, some of the languages, as the Lutuami, Shaste, and Palaihnik, being smooth and agreeable to the ear, while the Shoshoni and Kalapuya, though soft, are nasal and indistinct.' [1]

At the time when this description was written, I had formed no opinion as to the origin of these contrasted phonologies. I am now inclined to believe that the difference is due mainly to climatic influences. The harsh utterance extends from Alaska southward to the Columbia River, where it suddenly ceases, and gives place to softer sounds. This is exactly the point at which the coast ceases to be lined by that network of islands, straits, and friths, whose waters, abounding in fish, afford the main source of subsistence to the tribes of the northern region. The climate, except for a brief summer, is that of an almost perpetual April or October. This part of the coast is one of the rainiest regions of the earth, and the fishermen in their canoes are almost constantly exposed to the chilling moisture. Their pronunciation is that of a people whose vocal organs have for many generations been affected by continual coughs and catarrhs, thickening the mucous membrane and obstructing the air-passages. A strong confirmation of this view is found in Tierra del

[1] *Ethnography and Philology*, p. 533. The orthography here employed is somewhat different from that of Dr. Boas, who, by my advice, has avoided the use of Greek or other foreign characters, employing only English letters with various diacritical marks. This alphabet somewhat disguises to the eye the extreme difficulties of the pronunciation. The $t\chi l$, for example, is written by him simply *tl*, but the *l* is defined as an 'explosive *l*.' It is the combination so frequent in the Mexican (or Nahuatl) tongue.

Fuego, where apparently a climate and mode of life almost exactly similar have produced the same effect on the people and their language. Anyone who will compare my above-quoted description with the well-known and amusing account given by Darwin of the speech of the Fuegians will be struck by the resemblance. He writes, in his 'Voyage of the "Beagle"': 'The language of these people, according to our notions, scarcely deserves to be called articulate. Captain Cook has compared it to a man clearing his throat; but certainly no European ever cleared his throat with so many hoarse, guttural, and clicking sounds.' Yet the Fuegian language has been found to be, in its grammar and vocabulary (like the languages of our north-west coast), highly organised, and abounding in minutely expressive words and forms.[1]

South of the Columbia River the coast becomes nearly bare of islands. Harbours are few. The purely fishing tribes are no longer found. The milder climate of California, resembling that of Southern Italy, begins to prevail, and the soft Italian pronunciation pervades all the languages, except those of a few Tinneh septs which have wandered into this region from the far north, and still retain something of the harshness of their original utterance.

Not merely in their modes of speech, but also in more important points, do the northern coast tribes show a certain general resemblance, which, in spite of radical differences of language, and doubtless of origin, seems to weld them together into one community, possessing what may fairly be styled a civilisation of their own, comparable on a small scale to that of the nations of Eastern Asia. Dr. Boas is the first investigator whose researches have extended over this whole region. Other writers have given us excellent monographs on separate tribes. The work of Mr. Sproat on the Nootka, and those of Dr. Dawson on the Haida and Kwakiutl may be particularly mentioned. But a general description was needed to bring out at once the differences and the resemblances of the various stocks, and to show the extent to which similar surroundings and long-continued intercommunication had availed to create a common polity among them.

Two institutions which are, to a greater or less extent, common to all the coast tribes, and which seem particularly to characterise them and to distinguish them from other communities, may here be specially noted. Both appear to have originated in the Kwakiutl nation, and to have spread thence northward and southward. These institutions are the political secret societies and the custom of 'potlatch.' Secret societies exist among other Indian tribes, and probably among all races of the globe, civilised or barbarous. But there are perhaps no other communities in which the whole political system has come to be bound up with such societies. As Dr. Boas informs us, there are in all the tribes three distinct ranks—the chiefs, the middle class, and the common people—or, as they might perhaps be more aptly styled, nobles, burgesses, and rabble. The nobles form a caste. Their rank is hereditary; and no one who was not born in it can in any way attain it. The nobles have distinction and respect, but little power. The government belongs mainly to the 'burgesses,' who constitute the bulk of the nation. They owe their position entirely to the secret societies. Any person who is not a member of a secret society belongs to the rabble, takes no part in the public

[1] See Fr. Müller, *Grundriss von Sprachwissenschaft,* vol. iv. p. 207; and Max Müller's *Science of Thought*, p. 437.

councils, and is without consideration or influence. The greater the number of secret societies to which any man belongs, the higher is his standing in the community. As there are several of these societies in every tribe, it is evident that no person whose character would make him a desirable member of one of them is likely to remain outside of the burgess class. The lowest class, or rabble, is therefore a veritable residuum, composed of feeble-minded or worthless individuals, with, of course—in those tribes which practise slave-holding—slaves and their descendants. Grotesque as this system seems at first thought, further consideration shows it to be by no means ill-contrived for keeping the government of the tribe permanently in the worthiest hands, and bringing men of the first merit into the most influential positions.

Connected with this system is that of the 'potlatch,' or gift-festival, a custom which has been greatly misunderstood by strangers, who have regarded it as a mere parade of wasteful and ostentatious profusion. It is in reality something totally different. The potlatch is a method most ingeniously devised for displaying merit, acquiring influence, and at the same time laying up a provision for the future. Among these Indians, as among all communities in which genuine civilisation has made some progress, the qualities most highly esteemed in a citizen are thrift, forethought, and liberality. The thrift is evinced by the collection of the property which is distributed at the gift-feast; the liberality is, of course, shown in its distribution; and the forethought is displayed in selecting as the special objects of this liberality those who are most likely to be able to return it. By a well-understood rule, which among these punctilious natives had all the force of a law of honour, every recipient of a gift at a potlatch was bound to return its value, at some future day, twofold. And in this repayment his relatives were expected to aid him; they were deemed, in fact, his sureties. Thus a thrifty and aspiring burgess who, at one of these gift-feasts, had emptied all his chests of their accumulated stores, and had left himself and his family apparently destitute, could comfortably reflect, as he saw his visitors depart in their well-laden canoes, that he had not only greatly increased his reputation, but had at the same time invested all his means at high interest, on excellent security, and was now in fact one of the wealthiest, as well as most esteemed, members of the community.

We now perceive why the well-meant act of the local legislature, abolishing the custom of potlatch, aroused such strenuous opposition among the tribes in which this custom specially prevailed. We may imagine the consternation which would be caused in England if the decree of a superior power should require that all benefit societies and loan companies should be suppressed, and that all deposits should remain the property of those who held them in trust. The potlatch and its accompaniments doubtless had their ill effects, but the system clearly possessed its useful side, and it might perhaps have been better left to gradually decline and disappear with the rise and diffusion of a different system of economy.

The nature of the civilisation and industry which accompanied it may be shown by a brief extract from the report of Dr. George Gibbs, already referred to. In 1858 he visited a village of the Makahs, a Nootka tribe, near Cape Flattery. It consisted of two blocks of four or five houses each. These houses were constructed of hewn planks, secured to a strong framework of posts and rafters. The largest was no less than 75 feet long by 40 in width, and probably 15 feet high in front. In chests of large size and very neatly made, and on shelves overhead, were stowed the family chattels and stores, a vast and miscellaneous assortment. 'Mr. Goldsborough,' he adds, 'who visited the village in 1850, informed me that the houses generally were on an even larger scale at that time; that the chief's house was no less than 100 feet in length, and that about twenty women were busily engaged in it, making bark mats and dog-hair blankets.'

It is evident that these people differ in character and habits as widely from the Indians of the interior as the Chinese and Japanese differ from the Tartar nomads. The coast tribes of British Columbia are communities of fishermen, mechanics, and traders, with a well-defined political and commercial system. They were to all appearance especially suited for accepting the industrial methods of modern Europe; and it becomes a subject of interest to inquire into the probabilities of the future in this respect.

In this inquiry the element of the radical difference of stocks comes very distinctly into view. We find that, despite the superficial resemblance in polity and usages which has been noted among these tribes, their moral and intellectual traits, like their languages, remain widely dissimilar. These differences become strikingly apparent in reviewing the recent information given respecting the condition and progress of the British Columbian tribes in the valuable annual reports of the Canadian Department of Indian Affairs.

Thus the Kwakiutl people—known in these documents by the grievously disordered name of 'Kwaw-kewlth'—are described in a late report (1887) as 'the least advanced and most averse to civilisation of any in the province.' 'The missionaries of several Churches,' we are further told, 'have endeavoured to carry on mission work among them, but each was obliged to abandon them as hopeless, until, several years ago, the Rev. Mr. Hall, of the Church of England, was stationed there, and, in spite of all the obstacles and discouragements encountered by him, remained, and has apparently won the confidence of some of these poor, ignorant creatures.' In the following year the local agent reports some improvement, but adds that 'the school is not so well attended as could be desired. The children are not averse to learning, but their parents see in education the downfall of all their most cherished customs.' In 1889 he finds among them some signs of progress in the mechanic arts, and a willingness to give up some of their superstitions. 'Only to the potlatch,' he adds significantly, 'do they cling with great pertinacity.'

To understand these facts it should be known that the Kwakiutl, by virtue of their force of character, their stubborn conservatism, and what may be called, in reference to their peculiar creed and rites, a strong religious sentiment, held a high position, and exercised a prevailing influence among the neighbouring tribes. The changes introduced by civilisation have naturally been repugnant to them. They cling to their ancient customs and laws; and when these are set aside, the sense of moral restraint is lost, and the Spartan-like persistency which made them respected degenerates into a sullen recklessness, combined with an obstinate hostility to all foreign influences.

A remarkable contrast appears in the character and conduct of their northern neighbours, the Tsimshians. These are the people among whom Mr. Duncan had such distinguished success in founding his mission of Metlakahtla. According to the brief description given in H. H. Bancroft's 'History of British Columbia,' this mission, which was commenced in 1858, had in 1886 'developed into a town containing some 1,500 so-called civilised natives, with neat two-story houses and regular streets. The principal industry was the weaving of shawls. There were also a salmon cannery, with a capacity of 10,000 cases a year; a sash and door factory; and a sawmill and a brickyard. The church, built entirely by the natives, and the materials for which, with the exception of the windows, were of home production, had a seating capacity of nearly a thousand, and was one of the largest in British Columbia.'

The unfortunate events which resulted in the withdrawal of Mr. Duncan and five hundred of his people from the province need not be referred to here, further than by stating that they led to the appointment of a commission, composed of two members, representing respectively the Dominion and the Provincial Governments, to inquire into the condition of affairs in this quarter. The commissioners visited the various stations on the Tsimshian coast in the autumn of 1887, and presented a very able and interesting report, which is published in the volume of that year. Their descriptions fully confirm all that has been said concerning the great and indeed astonishing advances which have been made by these natives in all the ways of civilisation. Of the village of Kincolith, comprising a population of about two hundred, they say :—

'The houses are mostly on the plan of those at Metlakahtla, one and a half stories high, with a room for reception and ordinary use, built in on the space between each two houses. Some of the houses are single-story, and several "bay windows" could be seen. There are street-lamps and sidewalks, and the little village bears every indication of prosperity. The place was tidy and orderly, and the Indians evidently thriving and well-to-do.'

The larger town of Port Simpson, with a population estimated at about a thousand, is thus described: 'The Indian village, spread over a considerable area, with several streets and numerous houses, presented quite an imposing appearance. The houses are substantially built, and are varied in fashion by the taste of the natives. A long line of houses fronts upon an esplanade, commanding a fine sea-view, and another on Village Island faces the harbour. The cemetery on the extremity of this island is largely in modern style, and contains many costly monuments. The island is connected with the rest of the town by a 'long bridge.' There are a handsome church—said to rank next in size to the one at Metlakahtla, which is the largest in the province—a commodious school-house, and a well-conducted orphanage, all bearing testimony to the energy of those in charge of the mission. There are a fire-brigade house and a temperance hall; street-lamps are used; and a brass band was heard at practice in the evening. On the commissioners' arrival a salute was fired and a considerable display of bunting was made.'

The report of these impartial and liberal-minded commissioners shows that these Indians held themselves to be completely on a level with the white settlers, and that they felt a natural unwillingness to be confined to a 'reserve,' and to be placed under an 'Indian agent.' Their sentiments, manly and self-respecting, were precisely such as might have been expressed by a colony of Norwegians or Japanese, but with the added claim to consideration that the claimants regarded themselves as the rightful owners of the land, on which their people had resided from time immemorial.

The widespread bands of the great Salish people show many varieties of character, as might be expected in the septs of what is evidently a mixed race. The majority, however, are industrious, and readily adapt themselves to the new conditions of their present life. As fairly typical, the account which is given in the latest report (for 1889) of the Tl-kamcheen or Lytton band may be selected. This is the principal band of the 'Ntlakyapamuq tribe,' whose location will be found on the map near the junction of the Fraser and Thompson Rivers. The resourcefulness and versatile industry by which the members of this band manage to thrive under very adverse circumstances are well described by the local agent, Mr. J. W. Mackay: 'Although these Indians,' he observes, 'have had a large acreage allotted to them, but a very small portion of it can be cultivated, owing to the entire lack of water. These Indians are great traders and carriers. They draw the agricultural products which they require from the neighbouring reserves at Spapiam, N.humeen, Strynne, and N.kuaikin. They help the Indians of these reserves to sow and harvest their crops, and take payment for their services in kind. They mine for gold, carry goods for traders from Lytton to Lillooet, and work for the Canadian Pacific Railway Company. They own a large number of horses, which they pasture on the lands allotted to them. They have a few head of horned cattle, and they cultivate the few available plots of land belonging to their reserves. They are in good circumstances. They pay considerable attention to the offices of religion.'

The Cowichin tribe (on the map '*Kauitcin*'), on the south-east corner of Vancouver Island—another sept of this stock—are described as making fair progress, but as more unsettled in their habits. The recent statutory interference with some of their customs had produced a remarkable effect. Under the peculiar stimulus of their own system they had accumulated in 1888 'personal property' to the large amount of 407,000 dollars. In the following year that value had suddenly sunk to 80,000 dollars. This startling change is briefly explained by the Indian Superintendent for the Province: 'The decrease in the value of personal property as compared with last year,' he states, 'is ascribed by Mr. Agent Lomas to the fact that most of the natives have not collected property for potlatching purposes.' Thus it appears that a law of compulsory repudiation, enacted with the most benevolent motives, had in a single year reduced the personal wealth of one small tribe from over 400,000 dollars to a fifth of that amount. This must be deemed a lesson in political economy as striking as (coming from such a quarter) it is unexpected.

One of the smallest and, at the same time, most interesting of the tribes of this province are the Kootenays (Kutonaqa on the map). They number only about five hundred souls, and inhabit a spacious valley in the extreme east of the province, enclosed between the Rocky Mountains and the Selkirk Range. Their language is distinct from all other known idioms. In their customs they do not differ widely from the other interior tribes. Their chief distinction is in their moral character. In regard to this distinction all authorities agree. The Catholic missionaries, when they first came among them, were charmed with them. The Rev. P. J. De Smet, in his little volume of 'Indian Sketches,' writes thus enthusiastically concerning them: 'The beau-ideal of the Indian character, uncontaminated by contact with the whites, is found among them. What is most pleasing to the stranger is to see their simplicity, united with sweetness and innocence, keep step with the most perfect dignity and modesty of deportment. The gross vices which dishonour the red man on the frontiers are utterly unknown among them. They are honest to scrupulosity. The Hudson Bay Company, during the forty years that it has been trading in furs with them, has never been able to perceive that the smallest object had been stolen from them. The agent of the company takes his furs down to Colville every spring and does not return before autumn. During his absence the store is confided to the care of an Indian, who trades in the name of the company, and on the return of the agent renders him a most exact account of his trust. The store often remains without anyone to watch it, the door unlocked and unbolted, and the goods are never stolen. The Indians go in and out, help themselves to what they want, and always scrupulously leave in place of whatever article they take its exact value.'

This was written in 1861, but describes the Kootenays as the author found them on his first visit to them in 1845, when they were still heathen. In 1888 the report of the local agent, Mr. Michael Phillips, brief and business-like in its terms, entirely confirms this description: 'The general conduct of the Upper Kootenay Indians,' he writes, 'has been good. Not a single charge has been laid against any one of them for any offence during the last twelve months, nor has any case of suspected dishonesty or misconduct been brought to my notice. From conversations I have had with Major Steele, I should judge that they are in point of moral conduct far superior to the Indians of the North-West.' By the latter expression the writer evidently refers to the Indians of what are known as the 'North-West Territories' of Canada, east of the Rocky Mountains.

Finally, in the same year (1888) the Chief Superintendent of Indian Affairs for the Dominion adds his emphatic and decisive testimony to the good qualities of the Kootenays in a single line: 'They are a strictly moral, honest, and religious people.' [1]

Much more might be added, if the space at our command would allow, to show the great and very interesting differences which prevail among the tribes of British Columbia. The farther our investigations are carried, the more numerous and important the subjects of inquiry become. The experience of another year confirms the opinion expressed by me in the last report of the committee, that no other field of ethnological research is to be found in North America which equals this province in interest and value. Indeed it may be questioned whether anywhere on the globe there can be found within so limited a compass so great a variety of languages, of physical types, of psychical characteristics, of social systems, of mythologies, and indeed of all the subjects of study embraced under the general head of anthropology. And, finally, the facts given in the present and former reports show how rapidly the opportunities for preserving a record of these primitive conditions are passing away.

These rapid changes, in themselves for the most part highly beneficial, are due, in a large measure, to the action of the Canadian and Provincial Governments. As something has been said on this point, it is but just to add that a careful examination of the official reports, as

[1] It should be mentioned that these statements refer specially to the 'Upper Kootenays.' Of the 'Lower Kootenays,' who are partly within the United States' territory, and who appear to be of mixed origin, the accounts are less favourable.

well as of all the other evidence at hand, leaves a highly favourable impression in regard to the policy and methods which have been pursued by the Canadian legislatures and executive authorities in dealing with these tribes. If any mistakes have been committed, they have been due chiefly to defective information. The evidence presented by these reports is that of a careful and kindly guardianship, more considerate and liberal, perhaps, than any barbarous tribes, in the like situation, have ever before experienced.

Second General Report on the Indians of British Columbia. *By* Dr. Franz Boas.

Introductory Note.

In the report of the results of my reconnaissance in 1888 I have given a summary of the most important facts relating to the ethnology of British Columbia so far as known. According to instructions of the editor of these reports, Mr. Horatio Hale, on my last journey, in the summer of 1889, I paid special attention to the study of the Nootka and the Salish tribes. Certain results of my investigations among the Nootka made it necessary to collect some additional facts on the Kwakiutl. Therefore the following report will be devoted to a description of the Nootka, Salish, and Kwakiutl. The Salish stock inhabits a considerable part of the interior of British Columbia and the southern part of the coast. In describing the ethnology of this people the former group must be separated from the latter, which participates in the peculiar culture of the coast tribes of British Columbia. As the Salish are subdivided into a very great number of tribes speaking different dialects, I have thought it advisable to study one tribe of each group. Among the coast tribes I selected the Lku'ñgEn, among those of the interior the Shushwap. The first part of the report contains a description of the tribes or groups of tribes mentioned: the Lku'ñgEn, Nootka, Kwakiutl, and Shushwap. In my first report a sketch was given of four linguistic stocks of this region: the Tlingit, Haida, Tsimshian, and Kutonaqa. In the second part of the present report the review is completed, a sketch of the Kwakiutl, Nootka, and Salish languages being given. As the last is subdivided into a great number of dialects, it was necessary to select only the most salient points of the various dialects. This seemed the more advisable, as the Kalispelm dialect is well known through Mengarini's grammar and Giorda's dictionary. The measurements of crania were made in the anthropological laboratory of Clark University, Worcester, Mass., which is well fitted with the necessary instruments. The described specimens were collected in part by Mr. W. J. Sutton, of Cowitchin, B.C., in part by myself during the years 1886 to 1888. I have to express my thanks to Dr. N. L. Britton, of Columbia College, New York, for determining a number of plants for me. I am indebted to the kindness of Dr. George M. Dawson for photographs of specimens in the museum of the Geological Survey of Canada in Ottawa, from which a number of sketches were made.

The following alphabet has been used in the report:—

The vowels have their continental sounds, namely: *a*, as in *father*; *e*, like *a* in *mate*; *i*, as in *machine*; *o*, as in *note*; *u*, as in *rule*.

In addition the following are used: *ä*, *ö*, as in German; *â*=*aw* in *law*; E=*e* in *flower* (Lepsius's e̥).

Among the consonants the following additional letters have been used: *g*·, a very guttural *g*, similar to *gr*; *k*·, a very guttural *k*, similar to *kr*; *q*, the German *ch* in *bach*; H, the German *ch* in *ich*; Q, between *q* and H; *c*=*sh* in *shore*; *ç*, as *th* in *thin*; *tl*, an explosive *l*; *dl*, a palatal *l*, pronounced with the back of the tongue (dorso-apical).

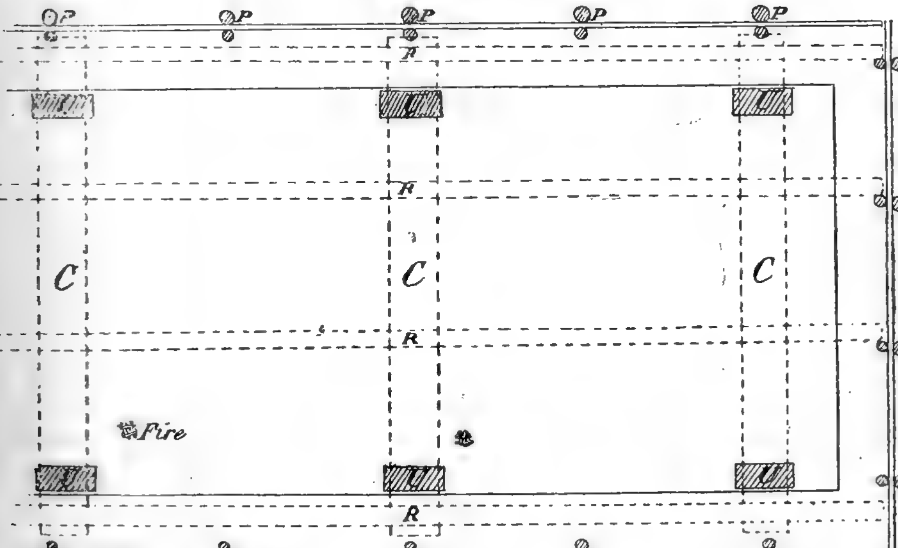
I. THE LKU'ÑGEN.

The Lku'ñgEn are generally known by the name of Songish. They inhabit the south-eastern part of Vancouver Island. They belong to the Coast Salish, a group of tribes of the Salish stock (see Fifth Report of Committee, p. 804). They are called Lkū'men by the Snanai'muQ. Their language is called the Lkuñgē'nEn. The same language, with very slight dialectic peculiarities, is spoken by the Qsā'nitc (Sanitch) of Sanitch Peninsula and on the mainland, south of Fraser River; the Sâ'ok of Sooke Inlet and the Tla'lam on the south side of Juan de Fuca Straits. The name of 'Songish' is derived from that of one of their septs, the Stsâ'ñgEs, who live south-west of Victoria.

HOUSES AND BOATS.

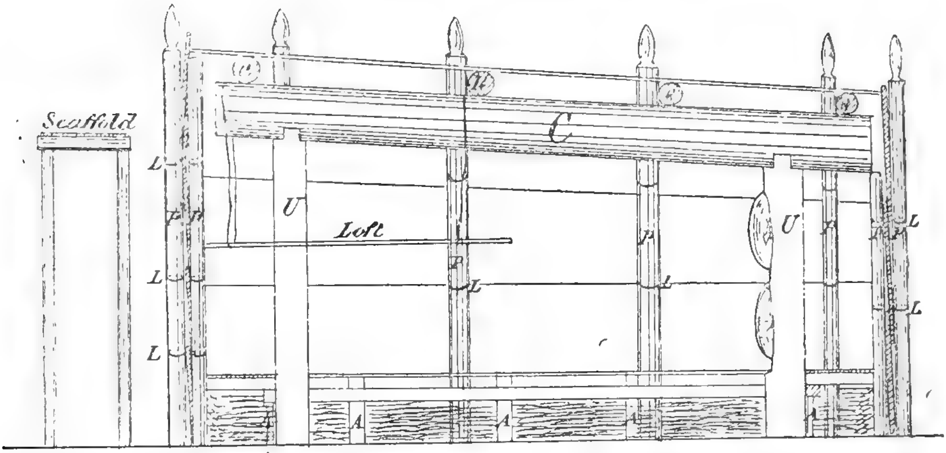
The Lku'ñgEn use the long houses of the Coast Salish. In British Columbia this type of house is used on the west coast of Vancouver Island, on the east coast, south of Comox, and on the coast of the mainland. In the upper part of the Fraser River delta subterrânean houses of the same type as those used in the interior of the province are used. The framework of the house consists of heavy carved uprights which carry heavy cross-beams. The uprights are generally rectangular (U, figs. 1, 2). The cross-beams, C, are notched, so as to fit on the top of

FIG. 1.—Plan of Lku'ñgEn House.



the uprights. The uprights which are nearest the sea are a little higher than those on the opposite side. The higher one of the long sides of the house faces the sea. A series of rafters, R, are laid over the cross-beams, C. Close to the uprights a number of poles are erected which are to hold the wall. They stand in pairs, the distance between the two poles of each pair corresponding to the thickness of the wall. The top of the outer poles is ornamented as shown in fig. 2, P. Heavy planks are placed

FIG. 2.—Section of Lku'ñgEn House.



between these poles, the higher always overlapping the lower so as to keep out the rain. They are held in place by ropes of cedar-branches which pass through holes in these boards and are tied around the poles, L. The uppermost board on the house-front serves as a moulding, hiding from view and closing the space between the rafters and the front of the house. The door is either at the side or, in very large houses, there are several on the side of the house facing the sea. The roof consists of planks as described in the Fifth Report of the Committee, p. 818. The uprights of the Lku'ñgEn house are carved and painted as shown in fig. 3. In some instances their surface is plain, but animals are carved on it, the whole being cut out of one piece. Such posts do not belong to the Lku'ñgEn proper, but were introduced into one family after intermarriage with the Cowitchin. The posts shown in fig. 4 belong to a house in Victoria, and the same figures are found in a house at Kua'mitcan (Quamichin), where the mother of the house-owner belongs. They represent minks. The human figures represent the spirits whom the owner saw when cleaning himself in the woods before becoming a member of the secret society Tcyiyī'wan (see p. 578). It is worth remarking that the faces of these figures are always kept covered, as the owner does not like to be constantly reminded of these his superhuman friends and helpers. Only during festivals he uncovers them. All along the walls inside the house runs a platform of simple construction. Posts about one foot high, A, are driven into the ground at convenient intervals. They are covered with cross-bars which carry the boards forming the platform. In some parts of the house shelves hang down from the rafters about seven or eight feet above the floor. Each compartment of the house, *i.e.*, the space between two pairs of uprights, is occupied by one family. In winter the walls and the dividing lines between two compartments are hung with mats made of bullrushes. The fire is near one of the front corners of the compartment, where the house is highest. The boards of the roof are pushed aside to let the smoke escape. Household goods are kept on the platform; here are also the beds. The bed consists

FIG. 3.—Upright of Lku'ñgEn House.

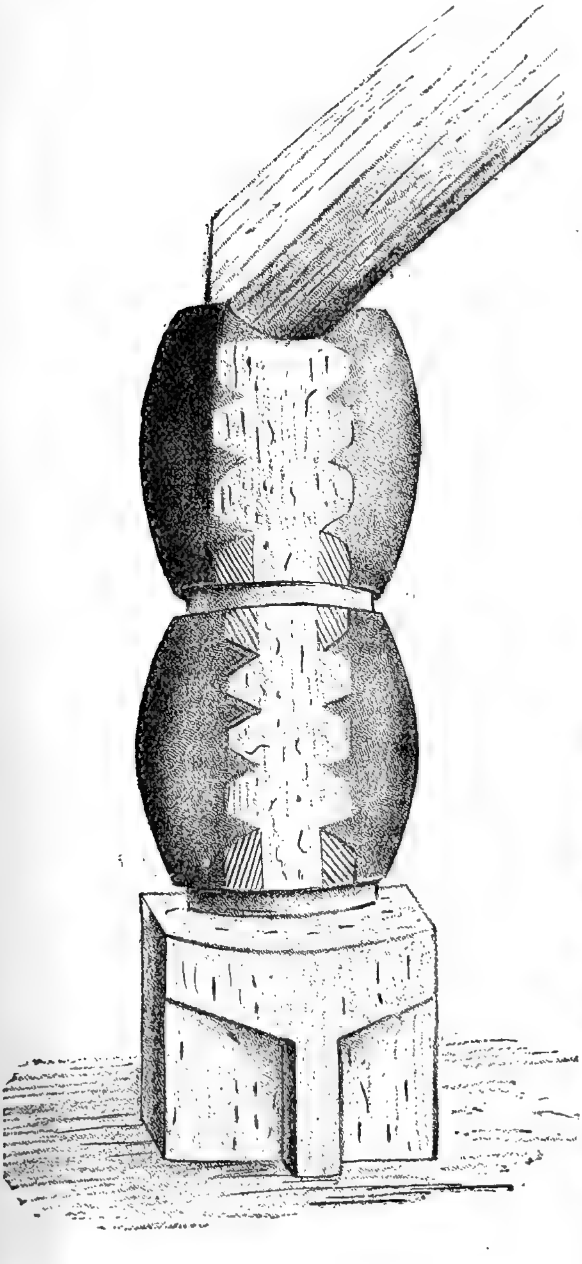
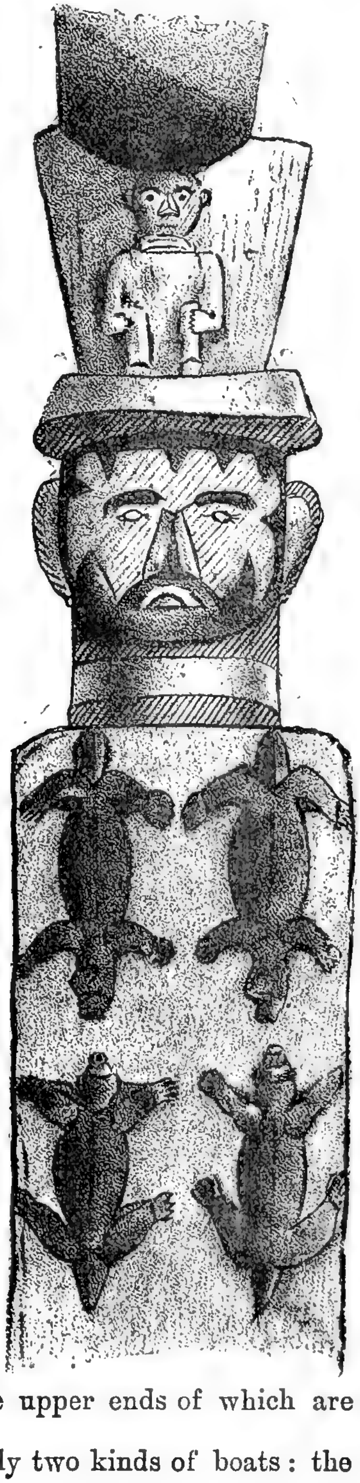


FIG. 4.—Upright of Lku'ñgEn House.

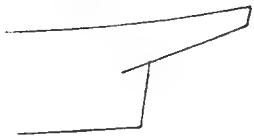


of a number of mats made of bullrushes, the upper ends of which are rolled up and serve as a pillow.

At the present time the Lku'ñgEn use only two kinds of boats: the small fishing-boat *snE'quatl* and the Chinook boat *â'tqEs*. The latter, however, is not an old style Lku'ñgEn boat, but belongs to the Nootka. The *snE'quatl* is a long, narrow boat with slanting stern, similar in shape to a small Kwakiutl boat; its peculiarity is the bow as shown in fig. 5.

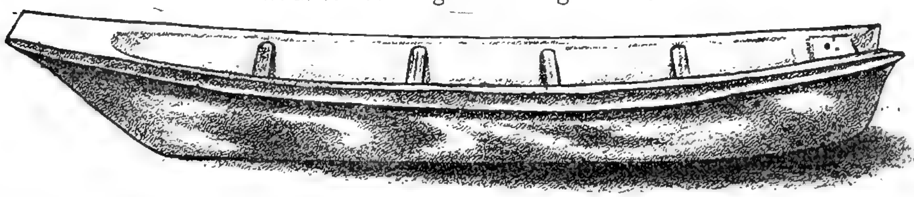
FIG. 5.

FIG. 6.



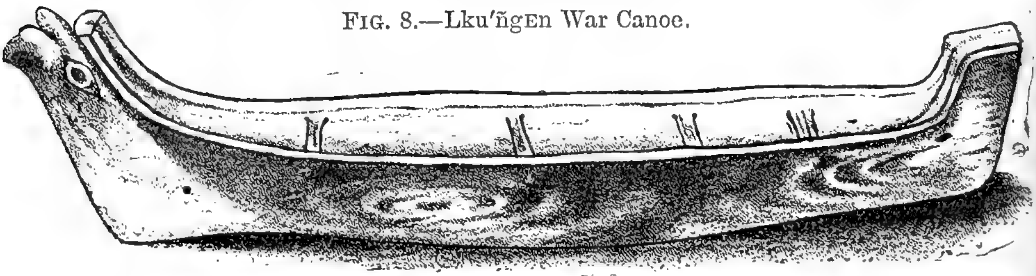
The Cowitchin boat has a stern similar to that of the Kwakiutl boat, fig. 6. It is called by the Lku'ñgEn *stī'uwaitatl, i.e.*, boat with a square bow. The Kwakiutl boat is called *pē'k·tlEntl* or *tc'ä'ätltq*. Besides the small

FIG. 7.—Lku'ñgEn Fishing Canoe.



boat, the Lku'ñgEn used the large fishing-boat called *stE'tlEm* or *tl'lā'i*, and the war-boat *kuinē'itl*. I have had models made of these boats; the former is shown in fig. 7, a lateral view of the latter in fig. 8. The

FIG. 8.—Lku'ñgEn War Canoe.



square stern is peculiar to the Lku'ñgEn fishing-boat. It seems that it was not made of one piece with the boat, but consisted of a board inserted into a groove, the joints being made water-tight by means of pitch.

MANUFACTURES AND FOOD.

I do not intend to give a detailed report on these subjects, but confine myself to describing such manufactures and such methods of preparing food as I had occasion to observe. Blankets are woven of mountain-goat wool, dog-hair, and duck-down mixed with dog-hair. The downs are peeled, the quill being removed, after which the downs are mixed with dog-hair. A variety of dogs with long white hair was raised for this purpose; it has been extinct for some time. The hair which is to be spun is first prepared with pipe-clay (*st'ā'uok·*).[1] A ball, about the size of a

[1] Dr. George M. Dawson obtained a specimen of this material from Indians in Burrard Inlet in 1875. It proved to be diatomaceous earth, not true pipe-clay. The material used by the Lku'ñgEn is found somewhere north-east of Victoria, the exact spot being unknown to me.

fist, of this clay is burnt in a fire made of willow wood; thus it becomes a fine, white powder, which is mixed with the wool or hair. The mixture is spread over a mat, sprinkled with water, and for several hours thoroughly beaten with a sabre-like instrument until it is white and dry; thus the grease is removed from the hair. Then it is spun with the hand on the bare thigh. The thread is worked into a basket; thus two baskets full of thread are made. Then the two threads are rolled up together on a stick and a large ball is made, which can be unrolled from the inner end. The latter is next fastened to the shaft of the spindle. The spindle has a shaft about three feet long, a heavy disc of whale's bone about a foot in diameter being fastened to its centre. When in use, the upper end of the shaft rests between the thumb and first finger of the left, while its lower end stands on the ground. It is turned with the right hand by striking the lower surface of the disc. Thus the two threads are twisted one around the other, and the double thread is rolled on the shaft of the spindle until the whole ball has been spun. These threads are used for a variety of purposes; for making blankets, for fringes, for making straps. The blanket is woven on a very simple loom. The cloth- and yarn-bars rest in two vertical posts, which have each slits for these bars. The ends of the bars turn in these slits. The bars are adjustable, wedges being inserted into the slits so as to regulate their distance. The warp is hung over the bars, passing over a thin stick which hangs in the middle between the bars. The weft is plaited in between the warp, beginning under the stick. Unfortunately, I am unable to describe the exact method of weaving. The weft is pressed tight with the fingers. The blankets have a selvage, which consists of a long thread with loops, that form a fringe when the blanket is finished. Some blankets of this style are made with black zigzag stripes.

Nettles serve for making ropes and nets. They are cleaned between a pair of shells, then split with a bone needle, dried, and finally peeled. The fibres are then spun on the thigh. Another fibrous plant called *ctcā'muk·*, which is found on Fraser River, is traded for and used for making nets. Red paint is not made by the Lku'ñgEn, but traded from the tribes on the mainland. Neither do they make cedar-bark mats, the manufacture of which is confined to the Kwakiutl and Nootka.

Burnt pipe-clay is used for cleaning blankets. The clay is spread over the blanket, sprinkled with water, and then thoroughly beaten.

Clams are prepared in the following way. They are opened by being spread over red-hot stones and covered with a mat; then they are taken out of the shell, strung on poles, and roasted. After being roasted they are covered with a mat and softened by being trampled upon. Next they are taken from the sticks on which they were roasted and strung on cedar-bark strips. In this shape they are dried and stored for winter use in boxes. They are eaten raw or with olachen oil.

Salal berries are boiled and then dried on leaves; the boiled berries are given the shape of square cakes. When eaten they are mashed in water.

The root of *Pteris aquilina* is roasted, pounded, and the outer part is eaten.

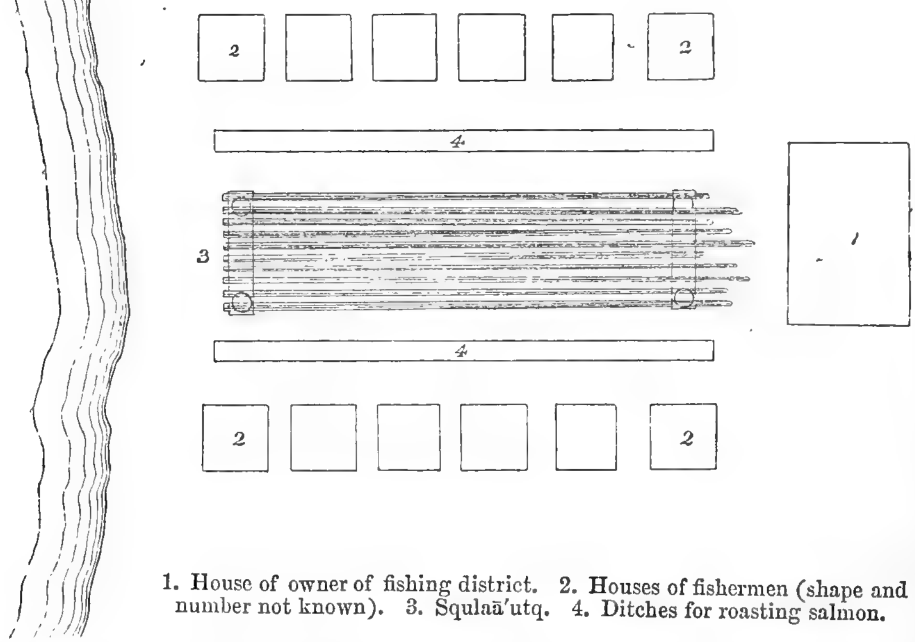
Haws are eaten with salmon roe.

On boat journeys the roots of *Pteris aquilina* and a species of onions called k·tlâ'ol, serve for food.

Salmon Fishing.

Every gens has its own fishing-ground. The chief of the gens will invite a number of families to help him catch salmon, and in return he feeds them during the fishing season. Shortly before the fishing season opens they collect bark, dry it, and make nets out of it. At the same time strong ropes of cedar-twigs are made with a noose at one end. They are fastened to heavy stones, which are to serve as anchors for the fishing-boats. Two such anchors are prepared and finally thrown into the water at the fishing-ground. The upper end of the rope is fastened to a buoy. When the men go out fishing a fishing-boat (*tl'lā'i*, see fig. 7) is fastened to each anchor and a net stretched between the two boats. When the net is full, one boat slackens the rope by which it is tied to the buoy and approaches the other, the net being hauled in at the same time. The fishing village is arranged in the following way (fig. 9). The centre is

Fig. 9.—Fishing Village.



1. House of owner of fishing district. 2. Houses of fishermen (shape and number not known). 3. Squlaā'utq. 4. Ditches for roasting salmon.

formed by the scaffold for drying salmon (*squlaā'utq*). It consists of two pairs of uprights carrying a cross-beam each, which support the long heavy beams on which the salmon are dried. These are cut off close to the supports nearest the sea, while at the other end their length is different, according to the size of the trees which were used in the construction. The house of the owner of the fishing-ground stands behind the scaffold. On both sides of the latter there are a number of huts. The crew of one boat lives on one side, that of the other on the other side. The owner appoints a chief fisherman (*kun'ā'liin*), who receives in payment the catch of two days and a few blankets. His hat is trimmed with fringes of mountain-goat wool. He divides the fishermen into two crews. On the day when the first salmon have been caught, the children must stand on the beach waiting for the boats to return. They must stretch their arms forward on which the fish are heaped, the head always being kept in the direction in which the fish are swimming, as else they would cease running. The children carry them up to the grassy place at the sides of the *squlaā'utq* and deposit them there, the heads always being kept in the same direction. Four flat stones are placed around the salmon, and the owner burns on each *Peucedanum leiocarpum*, Nutt., red paint, and bullrushes as an offering to the salmon. Then the men and women, who have painted their faces red, clean and open the salmon. Each boat's crew dig a ditch, about three feet wide and as long as the *squlaā'utq*, in front of their houses. Long poles are laid along the sides of the ditch and short sticks are laid across in a zigzag line. On these the salmon are roasted. The *kun'ā'liin* divides the salmon among the boats' crews. When they are done the children go to the ditch and each receives a salmon, which he or she *must* finish. For four days the salmon are roasted over this ditch. Everyone is given his share by the *kun'ā'liin*, but he must not touch it. The bones of the salmon that the children have eaten must not touch the ground and are kept on dishes. On the fourth day an old woman collects them in a huge basket, which she carries on her back, and they are thrown into the sea. She acts as though she were lame. On the fifth day all the men turn over the roasted salmon that had fallen to their share on the previous days to the *kun'ā'liin.* When they come back from fishing the women expect them on the beach carrying baskets. The salmon are thrown into these, and from this moment no notice is taken of the direction in which they lie. They are thrown down under the scaffold and the *kun'ā'liin* divides them into two parts, one for each crew. Then the women clean and split the fish and tie them together by twos with strings of carex. The men paint their faces and dress in their best blankets. They take long poles and stand in one row at the lower end of the scaffold, one at each beam on which the salmon are to be hung. A pair of salmon is hung on the point of each pole, and now the men push four times upward, every time a little higher, blowing at the same time upward before they hang up the salmon.

Social Organisation and Government.

The Lku'ñgEn are divided into the following gentes, each of which owns a certain coast-strip and certain river-courses on which they have the exclusive right of fishing, hunting, and picking berries. The following is a list of the gentes and the territory each occupies:—

1. Ququ'lEk· } Codboro' Bay.
2. LElE'k· } Codboro' Bay.
3. Sk·iñgē'nes, Discovery Island.
4. Sītca'nētl, Oak Bay.
5. Tck'uñgē'n } McNeill Bay.
6. Tcik·au'atc } McNeill Bay.
7. Qltlâ'sEn } McNeill Bay.
8. Quqoā'q } McNeill Bay.
9. Squi'ñquñ, Victoria.
10. Qsā'psEm, Esquimalt (=SqsE-mā'letl.
11. Stsâ'ñges } From Esquimalt to Beecher Bay.
12. K·ēk·ā'yēk·En } From Esquimalt to Beecher Bay.

Each gens has names of its own. There are three classes of people, the nobility, called *stlEtē'tlk·atl* (collective of *stlē'tlk·atl*, nobleman); the middle class, called *tlā'm'al*; and the common people, called *tl'ai'tcitl.* Each of these classes has also names of its own, so that a common man cannot use a middle-class name, a middle-class man cannot use a nobleman's name. Here are a few examples:—

Stsâ'ñges nobility names:

Males: Qtcī'tlem, Enqä'im, Tilsk·ä'inEm.
Females: QupQoā'p, Ts'Elē'qōya.
Tcik·au'atc common men: Ctcâ'satl, Ham.

I was unable to ascertain the derivation of any of these names.

Common people may rise to the rank of the middle class by giving feasts, but middle-class people can never become noblemen. Wealth gives personal distinction only, not inheritable rank. The children of middle-class people are born common people. In order to raise their rank their parents or uncles give a feast, and distribute a certain amount of property in their behalf. By this means they become middle-class people, and are given a middle-class name. There is a complete scale of names, each being higher in rank than the other. By giving a number of festivals the child's rank can be raised higher and higher, until it obtains a high position among the middle class. In the same way the children of noblemen are given names of chiefs of higher and higher rank. The nobility have the privilege of dancing with masks.

The Lku'ñgEn gentes have no crests, particularly not the Sqoā'ēqoē, which belongs to a number of tribes of the Coast Salish; the Çatlō'ltq, Snanai'muQ, K·oā'ntlem, and probably several others. In one house in Victoria the mink (fig. 4) is found carved on the upright. It does not belong, however, to the Lku'ñgEn, but the owner's wife, who belongs to a Cowitchin family, gave it to her husband when they were married. The couple have an only daughter, who will inherit this crest.

The chief of the tribe (siä'm) belongs, of course, to the nobility. When giving a great 'potlatch' to his own and neighbouring tribes, which is his privilege, he stands on a scaffold which is erected in front of his house and lets his daughter or son dance by his side before distributing the property. The elevation of the scaffold may be seen in fig. 2. In case of war, chiefs are forbidden to fight in the front ranks, but are carefully protected, as their death would be considered a severe loss to the tribe.

After the death of the chief the chieftaincy devolves upon his eldest son. If he has none his younger brother and his descendants succeed him. A daughter or a son-in-law cannot succeed him. The new chief takes the name of the deceased, and when doing so has to give a great festival.

In war a war-chief is elected from among the warriors. War expeditions are confined to nightly assaults upon villages. Open battles are avoided. An expedition on which many men are lost, even if successful in its object, is considered a great misfortune to the tribe. Fires are burnt on mountains to notify distant villages or individuals that some important event has taken place.

Slaves were held by all classes. They were either captives or purchased from neighbouring tribes.

If a man has offended a foreign tribe, all members of his own tribe are liable to be seized upon, being held responsible for all actions of any one member. Therefore it is considered condemnable to offend a member of a foreign tribe, and when, for instance, a man has stolen something from a foreign tribe, and is found out by his own people, the chief will compel him to return the stolen property. A man who is offended has the right to take revenge at once. If he does not do so the perpetrator has the right to pay off his offence.

It may be mentioned here that sometimes men assume women's dress and occupations, and *vice versâ*. Such individuals are called *st'o'mEtcE*. This custom is found all along the North Pacific coast.

Gambling and Pastimes.

1. *Smētalē'*.—A game at dice is played with four beaver-teeth, two being marked on one of their flat sides with two rows of small circles. They are called 'women' (*slā'naē smētalē'*). The two others are marked on one of the flat sides with cross-lines. They are called 'men' (*suwē'k·a smētalē'*). One of them is tied with a small string in the middle. It is called *iHk·ak·'ē'sen*. The game is played by two persons. According to the value of the stakes, thirty or forty sticks are placed between the players. One begins to throw. When all the marked faces are either up or down he wins two sticks. If the faces of the two 'men' are up, of the two 'women' down, or *vice versâ*, he wins one stick. When the face of the *iHk·ak·'ē'sen* is up, all others down, or *vice versâ*, he wins four sticks. Whoever wins a stick goes on playing. When one of the players has obtained all the sticks he has won the stake.

2. *SlEhä'lEm*, or *wuqk·'ats*, is played with one white and nine black discs. The former is called the 'man.' Two players take part in the game. They sit opposite each other, and each has a mat before him, the end nearest the partner being raised a little. The player covers the discs with cedar-bark and shakes them in the hollow of his hands, which are laid one on the other. Then he takes five into each hand and keeps them wrapped in cedar-bark, moving them backward and forward from right to left. Now the opponent guesses in which hand the white disc is. Each player has five sticks lying in one row by his side. If the guesser guesses right he rolls a stick over to his opponent, who is the next to guess. If the guesser guesses wrong, he gets a stick from the player who shook the discs, and who continues to shake. The game is at an end when one man has got all the sticks. He has lost. Sometimes one tribe will challenge another to a game of *slEhä'lEm*. In this case it is called *lEhälEmē'latl*, or *wuqk·atsē'latl*.

3. *K·k·oiä'ls*.—A game at ball; the ball, which is made of maple knots, is called *smuk*. It is pitched with crooked sticks and driven from one party to the other.

4. *Hqwauā'latcis*.—The game of cat's cradle. A great variety of figures are made. Only one person is required to make these figures. Sometimes the teeth must help in making them.

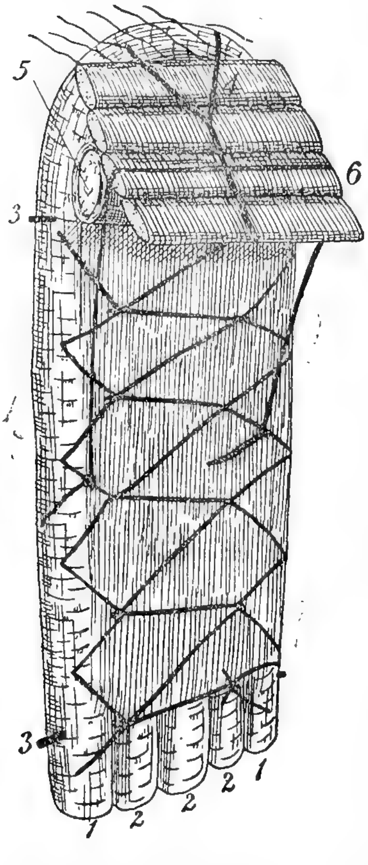
This is only a partial list, containing only those games of which I obtained descriptions. Besides these, throwing and catching of hoops is a favourite game. In gambling, the well-known sticks of the northern tribes are often used, or a piece of bone is hidden in the hands of a member of one party, while the other must guess where it is.

It is considered indecent for women to look on when the men gamble. Only when two tribes play against each other are they allowed to be present. They sing during the game, waving their arms up and down rhythmically. Men and women of the winning party paint their faces red.

Customs referring to Birth, Marriage, and Death.

During the period of pregnancy, women take off bracelets, anklets, and necklace. This custom, which is also found among the Nootka, probably means that there must be no stricture around the body which might hinder birth. They must also bathe regularly in the sea. When the time of delivery approaches, the parents engage an old man to cut the cedar-branch from which the cradle is to be suspended, and five old women to soften the cedar-bark to be used for bedding the babe in the cradle. They are paid for their services. There are no professional midwives, but sometimes the sī′ōua (see p. 580) is called to accelerate birth. The navel-string is cut with a broken shell by an old woman. The child, as soon as it is born, is smeared with bear grease and dogfish oil, particularly the navel and any sore parts of the skin. On the first day the child does not get any food. As soon as it is born the mother rubs it from the mouth towards the ears, so as to press the cheekbones somewhat upward. The outer corners of the eyes are pulled outward that they may not become round, which is considered ill-looking. The calves of the leg are pressed backward and upward, the knees are tied together to prevent the feet from turning inward. The forehead is pressed down. They have a saying referring to children who have not been subjected to this treatment, and, therefore, according to Indian taste, ill-looking: *tōu ō′wuna täns ksEtctcā′ai*, that means, 'as if no mother had made you look nice.' It is doubtful whether this treatment, except the flattening of the head, which is continued through a long period, has any effect upon the shape of the face. I do not believe that it has, at least not upon bones, as the effect would be that of producing chamæconchic orbits, while, in fact, they are very high. If there is any change of form of the face, a question to which I shall refer later on, it is more probably due to the deformation of the cranium. The child is first strapped on to a cradle made of bullrushes. The latter comprise five bundles of rushes, each about an inch or an inch and a half in diameter. The outer one, fig. 10 (1), is given the shape of a horse-shoe; the others, which have only about half the length of the former, are placed inside the horse-shoe, parallel to its sides, so that they fill the intervening space and form a flat surface (2). These bundles are kept in place by two sticks (3), one being pushed through them near the curve, the other near the end. The curved part is to be the head end of the cradle. Both sides of the outer bundle are set with loops made of a thin rope, which serve for fastening the baby to the cradle. A larger loop (4)

Fig. 10.—Lku′ñgEn Cradle.



is attached to the curve. This frame is covered with a layer of fine cedar-bark. This layer is made of fibres of double the length of the cradle-board or frame. They are combed and carefully stretched out. Then a roll of bark about two inches wide by one inch high is laid on the middle part of the layer, and the fibres are doubled up so as to cover the roll. The fibres are plaited together with a thread of mountain-goat wool close to the roll, and thus keep it in place. A fringe of wool is fastened to the roll which forms the pillow of the infant (5). On top of the infant's head a cushion for pressing down the forehead is fastened (6). It consists of a series of flat rolls of cedar-bark, covered with a layer of fibres of cedar-bark in the same way as the pillow. Each roll is held in place by a plaiting of mountain-goat wool thread. The upper end of the cushion is also set with a fringe of this material. Between the cushion and the head a thick veil of cedar-bark is placed. This is made by drawing bundles of long fibres of cedar-bark through a cord of mountain-goat wool thread. The fringes lie over the head and occiput of the infant joining the pillow. The cord from which the veil hangs down lies across the forehead. The cushion is placed on top of this veil, so that its fringes hang down at the occiput of the child, while the plain edge lies near the forehead. A string is attached to the centre of the cord of the veil, and pulled backward over the cushion to the loop fastened to the curve of the cradle-board, to which it is fastened. Under the compressing cushion at both sides of the face rolls of cedar-bark are placed and pressed against the head, their upper end being also ornamented with fringe of mountain-goat wool thread. Then a cord is tied over the cushion and pulled downward to the third or fourth loop on the sides of the cradle. Thus a strong pressure is brought to act upon the region of the coronal suture. A cord of mountain-goat wool passes from side to side over the cradle and holds the infant. The face is covered with a hood-like mat to keep off the flies. When the child is about a month old it is placed in a wooden cradle. This is shaped like a trough. An inch or two above the bottom a kind of mattress is fastened, which consists of longitudinal strips of cedar-wood tied to two cross-pieces. The latter are tied to the sides of the cradle. In the bottom of the trough there is a hole for the refuse to run off. At the foot end there is a small board, ascending at an angle of about 30°, on which the child's feet rest, so that they are higher up than the head. The child is fastened in this cradle in the same way as on the first. The cradle is suspended from a cedar-branch, which is fastened to the wall or set up still attached to its trunk. It is worked by means of a rope attached to the point of the branch. For some time after birth the husband must keep at some distance (or out of sight?) from his wife, and must bathe and clean himself in the woods, that the child may become strong. Both parents are forbidden to eat fresh salmon. When the woman first rises from her bed after the child has been born, she and her husband must go into the woods and live there for some time. They make a camp in which they remain. Early in the morning one (doubtful which) goes eastward, the other westward, and bathe and clean themselves with cedar-branches. They stay in the woods about a month. As soon as the child is able to walk, the cradle and the branch from which it was suspended are deposited at certain places above high water. One of these points used to be where the Hospital of Victoria now stands. Its name is P'â'latsᴇs (=the cradles); another, the point Qᴇqē'leq, the third point east of Beacon Hill.

Twins, immediately after birth, possess supernatural powers. They are at once taken to the woods and washed in a pond in order to become ordinary men. If the twins are girls, it is an indication that a plentiful supply of fish will come. If they are boys, they will be good warriors.

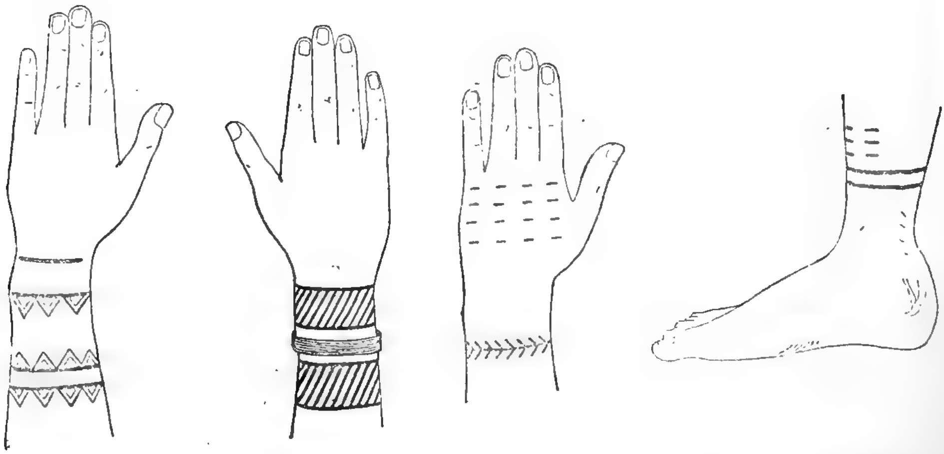
It seems that the women are held responsible for the behaviour of their children, for if a child cries the husband may beat his wife.

While children, and when reaching maturity, they must go frequently into the woods and bathe and clean themselves, in order to become strong and healthy. Girls, even before reaching maturity, must not eat parts of fish near the head, but only tails and adjoining parts, in order to secure good luck in their married life. On reaching maturity they have to observe numerous regulations. They must eat only dried fish; they may eat fresh clams. Gooseberries and crab-apples are forbidden, as it is believed that they would injure their teeth. When a girl has left the house she must return in such a direction that the sun is at her back when she starts to return, and then walk in the direction the sun is moving. At Victoria the girl, when reaching the age of puberty, must take some salmon to a number of large stones not far from the Finlayson Point Battery (see p. 578). This is supposed to make her liberal. She will also visit the hill PEtlē'wan, not very far from Cloverdale, on the summit of which is a small pond. She will dip her hand into the water and slowly raise the hollow hand. If she finds some grass, &c., in it she will expect to become rich and a chief's wife, else she will become a poor man's wife. (The name PEtlē'wan refers to this custom, being derived from *tlä'pEt*, to feel around.) Young men and women must not live luxuriously; then they will become rich in later life. They must not eat while the sun is low, as they believe it to be detrimental to health. Old people may eat at any time.

Menstruating women must not come near sick persons, as they would make them weak (*t'k·ēl*).

The lobes of the ear and the helix are perforated while the child is young. After the operation they have to abstain from fresh fish. Arms

FIG. 11.—Tattooing.



and chins of women are tattooed when they reach maturity. I have seen three diverging lines running from the lip downward on the chins of a few old women. Fig. 11 shows designs on the arms and hands of two women of about fifty-five and seventy years of age. The tattooing is done by women, charcoal of bullrushes being introduced under the skin by means of a needle that is held horizontally.

When a man, particularly a chief's son, wants to marry, two old people are sent to the girl's parents to ask for the girl. They are called *k·ulnā'kuñ.* At first the girl's parents refuse. Then the *k·ulnā'kuñ* are sent back with a large supply of food which they present to the girl's parents. They accept it, but do not eat it. They give it to the dogs. The messengers however, persevere, until the parents give their consent. Then the young man goes to the girl's house in the evening and sits down near a post, where he remains for four days. When he becomes tired he leaves the house for a short time, but returns to his former place after a few minutes. During these days he does not eat, but drinks a little water only. He remains at the post and does not come near the fire. Finally the girl's parents send two old people to lead him to the fire, where a mat is spread for him; but he must not yet sit near the girl. Her parents prepare a good meal, but he eats very little only, carrying the full dishes to his mother. On the next day he returns home, and his family give many and valuable presents to the girl's father, which are carried there by young men. They do not go near the fire, but sit down on a place that is offered to common people only, in the middle of the house, or at the foot of a post. The girl's father has the presents piled up in one corner of the house and pays the messengers. Then the bride is led to the young man. Her father delivers a speech, and gives her presents of the same value as those received from the young man's father. The messengers take the bride to the young man's house. The parents of both husband and wife continue to send presents to each other, and to the couple for a long time. The latter are particularly supplied with food by both parents.

After death the face and the head of the body are painted red, and the female relations of the deceased wail for him. The body is at once taken out of the house through an opening in the wall from which the boards have been removed. It is believed that his ghost would kill everyone if the body were to stay in the house. A man who does not belong to the gens of the deceased (?) is engaged and paid for arranging the burial. He is called *mEk'āiĕ'ngatl.* Rich people and chiefs are buried in canoes which are placed under trees; poor people are wrapped in mats or mountain-goat wool blankets (the knees being drawn up to the chin) and placed on branches of trees. The body, after being wrapped up, is frequently put into a box. It seems that in olden times the body was doubled up and then covered with heavy stones. Such cairns are found all over the south-eastern part of Vancouver Island. The implements of the deceased are deposited close to the body, else his ghost would come and get them. Sometimes even his house is broken down. Two or three days after burial food is burnt near the grave. At times food is set aside for the deceased by his friends. After burial the whole tribe go down to the sea, wash their heads, bathe, and cut their hair. The nearer related a person is to the deceased the shorter he cuts his hair. Those who do not belong to the deceased's family merely clip the ends of their hair. The hair that has been cut off is burnt or buried. At a chief's death one or two of his slaves used to be killed and buried with him. Widow and widower, after the death of wife or husband, are forbidden to cut their hair, as they would gain too great power over the souls and the welfare of others. They must remain alone at their fire for a long time, and are forbidden to mingle with other people. When they eat nobody must see them. They must keep their faces covered for ten days. They fast for two days after burial and are not allowed to speak. After two days they may speak a little, but before addressing anyone they must go into the woods and clean themselves in ponds and with cedar-branches. If they wish to harm an enemy they call his name when taking their first meal after the fast and bite very hard in eating. It is believed that this will kill him. They must not go near the water, or eat fresh salmon, as the latter might be driven away. They must not eat warm food, else their teeth would fall out. The names of deceased persons must not be mentioned. Levirate is practised. The brother or cousin of a man marries his widow, and a widower marries either his wife's sister or cousin after her death.

Medicine, Omens, and Beliefs.

Most of the medicines used by the Lku'ñgEn have no real relation to the disease for which they are used, but an imaginary one only. In many cases this connection is founded on a certain analogy between a property of the medicine and the desired result. This will become clear after reading the following list. I am indebted to Dr. N. L. Britton for the determination of the various plants.

Sedum spathulifolium, Hook.—The plant is chewed by women in the ninth month of pregnancy every morning to facilitate birth.

Pteris aquilina.—Leaves (*sEkä'n*) are chewed by children. They produce a considerable flow of saliva, which children use for washing their hands before eating fresh salmon. They must not use water for this purpose. The root (*sk·u'yuq*) is eaten (see p. 567).

Berberis aquifolium (*sk·oā'tcasītltc*).—The stem is pounded and boiled. The decoction is drunk as a remedy against skin diseases, particularly against syphilis, and to strengthen the body. The fruits (*sk·oā'tcas*) are eaten raw or boiled.

Abies grandis, Lindl. (*skumē'ik·s*).—The branches are warmed and applied to the stomach and sides as a remedy against pains of the stomach or sides.

Aspidium munitum, Kaulfuss (*sqä'lEm*).—Spores removed and dried. They form a fine powder, which is put on sores and boils to dry up the flowing pus.

Symphoricarpus racemosus, Michx.—Fruits rubbed on sores, and applied to the neck (under the chin) as a remedy against sore throat.

Achillea Millefolium (*tl'k·oē'tltc*).—Soaked in water, pounded and used as a poultice on head against headaches.

Rumex salicifolius, Weinmann.—Roots boiled and applied to swellings in form of a poultice.

Claytonia Sibirica (*sqoā'ñgitEn*).—Applied to head as a remedy against headaches.

Alnus rubra, Bongard (*skoā'ñgatltc*).—Fruits burnt to powder, which is spread over burns. The cambium (*qa'mqam*) is scratched from the tree and eaten.

Rubus Nutkanus, Moc. (*sk·ulñuquī'tltc*).—The green berries (sk·ulā'lEñuq) are chewed and spread over swellings.

Thuja gigantea, Nutt.—The inner layer of the bark is pulverised, laid on swellings, and then ignited. It burns slowly and serves the purpose of cauterisation. The bark of a tree named *k'·tlemē'ltc* is used for the same purpose.

Rheumatism.—The skin is scratched with sharp shells and then rubbed with either *ts'ᴇtqcätltc* or *k·u'nitlp.* I do not know what plants these are.

Carex sp.—Eaten to bring about abortion, or when the menses are irregular. As the edges of the leaves are sharp it is supposed that they will cut and thus kill the embryo, and that they will cut the inside of the woman, thus producing the menses.

Populus trichocarpa, S. and Gr. (*pk·'ē'letltc*).—Fruits pulverised and mixed with fish oil, used as hair oil to make the hair grow. The fruits are found high up on the tree—a long way up, therefore they will make the hair long.

Wasps' nest.—Decoction of wasps' nest or of flies drunk by barren women to make them bear children, as both bring forth many young.

Wasps are burnt and the faces of warriors are rubbed with the ashes, before they go on a war expedition, to make them brave. Wasps are warlike insects, and therefore will make the warrior brave like themselves.

Osmorrhiza nuda, Torr.—Roots chewed by girls in spring as a love-charm. The girl first bathes, then chews the root and rubs the saliva on her left arms upwards towards the heart, at the same time naming the man whose love she wishes to win. Then she rubs the saliva with the left hand up the right arm towards the heart, speaking her own name. She ends the latter motion in such a way that the hand remains above the place where she put the young man's name. Thus her own name is placed above his and she has conquered him.

Peucedanum leiocarpum, Nutt. (*k·ᴇqmē'n*).—This plant is one of the most powerful 'medicines.' It is burnt to drive away ghosts. The first salmon of the season are roasted on it, and it is used in carrying them to the house. It is chewed and the juice swallowed as a remedy against cough. A poultice of *k·ᴇqmē'n* is spread on the head to cure headache.

To spit water on a sick person alleviates his pain.

Fractured bones are bandaged by means of the outer layer of cedar-bark. In complicated fractures the splinters of bone are first removed, then the limb is bandaged.

Rattlesnake poison is obtained by trade from the tribes on the upper Fraser River and on Thompson River. A powder of human bones is drunk as an antidote.

Omens.—Sneezing, ringing of the ear, twitching of muscles on right side are good omens, on left side bad omens. These also mean that people are speaking good or ill of the person according as the sensation is felt on the right or the left side. When one feels a weight on the breast or a fluttering of the heart, or when one must sigh, it indicates that something ill will happen to a relative or friend. When the lower eyelid twitches it indicates that one will weep. When an owl alights near a house and moves but little, husband or wife will die. When a large owl cries near the village, someone will die. To dream something ill of someone means that he will have bad luck.

An arrow or any other weapon which has wounded a man must be hidden, and care must be taken that it is not brought near the fire until the wound is healed. If a knife or an arrow which is still covered with blood of a man is thrown into the fire the wounded man will become very ill.

Menstruating women must keep away from sick persons, or else the latter will become weak.

There are a number of large stones not far from 'the Battery' in Victoria; when they are moved it becomes windy. If a man desires a certain wind he moves one stone a very little from its place, each stone representing one wind. If he should move it too much the wind would be very strong.

Certain herbs which secure good luck are fastened to the door of the house.

Gamblers use the same method to secure good luck. All these charms must be kept secret, and nobody must know what the charm of a man is, else it would lose its power.

Dreams come true. If one dreams of some future events that seem highly desirable, they will not come to pass if one speaks about the dream.

Secret Societies.

The Lku'ñgEn have two secret societies: the Tcyiyī'wan and the QEnqanī'tEl (= dog-howlers). Any member of the tribe may join the Tcyiyī'wan. For this purpose he goes into the woods and stays there for some time, continually bathing in lakes and washing his body with cedar-branches. The novice is called Qausā'lokutl. Finally he dreams of the dance which he is to perform and the song he is to sing. In his dream his soul is led all over the world by the spirit who gives him his dance and his song. Then he returns to the village. According to what he has dreamt he belongs to one of five societies which constitute the Tcyiyī'wan: (1) the Sk·ē'iep, who dance with their elbows pressed to the body, the arms extended forward and continually moving up and down; (2) the Nuqsoā'wēk·a, who jump around in wild movements; (3) the Sk·ä'k·oatl, who dance in a slow movement; (4) the Sk·oiē'lec, whose dance is similar to that of the Sk·ē'iep; and (5) the Tcilk·tE'ñEñ (derived from *tcâ'lok·*, woods). The general name of the dances of the Tcyiyī'wan is Mē'itla, which word is borrowed from the Kwakiutl. When the novice returns from the woods he teaches his song to the members of the society to which he is to belong for two days. Then the dance is performed, and henceforth he is a regular member of the secret society.

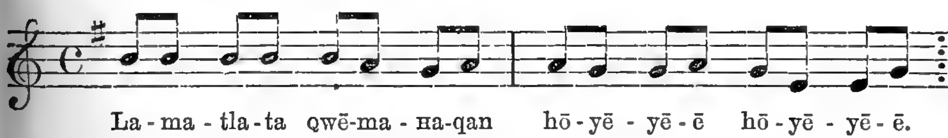
The QEnqanī'tEl, the second secret society, are also called Tlōkoa'la and Nō'ntlEm, although the first name is the proper Lku'ñgEn term. The Lku'ñgEn say that they obtained the secrets of this society from the Nootka, and this is undoubtedly true. I pointed out in my last report that the secret societies which we find on the North Pacific coast evidently spread from the Kwakiutl people. The facts collected on the southern end of Vancouver Island corroborate this opinion. The names Tlōkoa'la and Nō'ntlEm both belong to the Kwakiutl language, and are also used by the Nootka to designate their winter dances (see p. 599). The secrets of these societies spread from the Nootka to the Lku'ñgEn, Tla'lam, and the tribes of Puget Sound. The Tc'â'tEtlp, a sept of the Sanitch tribe, also have the Nō'ntlEm; while the Snanai'muQ, the Cowitchin, and the tribes of Fraser River have not got it. The Comox and Pentlatch obtained it through intermarriage with both the Kwakiutl and the Nootka. The right to perform the Nō'ntlEm is jealously guarded by all tribes who possess it, and many a war has been waged against tribes who illegitimately performed the ceremonies of the society. Its mysteries were kept a profound secret, and, if a man dared to speak about it he was torn to pieces by the K·uk·k·'ē'lEñ, about whom I have to speak presently. Only rich people can become members of the QEnqanī'tEl, as heavy payments are exacted at the initiation. If the father of the novice is not able to pay them, his relatives must contribute to the amount required. The initiation and the festivals of this society take place in winter only. When a young man is to be initiated his father first invites the QEnqanī'tEl to a feast which lasts five days. During these days mask dances are performed, which those who are not members of the society are also permitted to witness. They occupy one side of the house in which the festivities take place, while the QEnqanī'tEl occupy the other. The latter wear head-ornaments of cedar-bark and have their hair strewn with down. The faces of all those who take part in the festival are blackened. At the end of these days the father of the novice invites four men to bathe his son in the sea. One of them must wash his body, one must wash his head, and the two others hold him. In return they receive one or two blankets each. During this ceremony the K·uk·k·'ē'lEñ, who are described as 'wild men,' dance around the novice. They have ropes tied around their waists, and are held by other members of the society by these ropes. Then the QEnqanī'tEl lead the novice into the woods, where he remains for a long time, until he meets the spirit who initiates him. It seems that during this time he is secretly led to the house in which the QEnqanī'tEl continue to celebrate festivals at the expense of the novice's father, and there he is taught the secrets of the society. During this time, until the return of the novice from the woods, the house is tabooed. A watchman is stationed at the entrance, who keeps out uninitiated persons. During the absence of the novice his mother prepares cedar-bark ornaments and weaves mountain-goat blankets for his use. One afternoon he returns, and then his father gives a feast to let the people know that his child has returned. The latter performs his first dance, in which he uses masks and cedar-bark ornaments. This dance is called NuqnEä'mEñ. On this day the father must distribute a great number of blankets among the QEnqanī'tEl. The uninitiated are permitted to take part in the feast, and sit on one side of the house. The new member spends all his nights in the woods, where he bathes. In spring the new member, if a man, is thrown into the sea, and after that is free from all regulations attending the initiation. One of the principal regulations regarding novices of the QEnqanī'tEl is that they must return from the woods in the direction in which the sun is moving, starting so that the sun is at their backs. Therefore they must sometimes go in roundabout ways. They must go backward through doors which are *stlā'lEk·am* against them (see below). Frequently the sī'ōua is called to bespeak the door in their behalf before they pass through it. Before their dance the sī'ōua must also address the earth, as it is supposed that else it might open and swallow up the dancer. It is also *stlā'lEk·am* against the novice. The expression used is that the earth would 'open its eyes' (*k'u'nalasEn*), that means, swallow the novice. In order to avert this danger the sī'ōua must 'give name to the earth' and strew red paint and feathers over the place where the novice is to dance.

Religion and Shamanism.

All the tribes of the Coast Salish, from Comox to Puget Sound, believe in the Great Transformer, who is called *Kumsnō'otl* (=our elder brother) by the Çatlō'ltq of Comox, *Qā'is* by the Sk·qō'mic, and *Qäls* by all other tribes. The Lku'ñgEn pray to him, and expect that he will again descend from heaven at some future time and again wander all over the earth, punishing the bad. Their dances are said to be performed to please him. Although it seems probable that there exists some connection between Qäls and the sun, I have found no clear evidence showing this to be the case. It is said that Qäls made the sun and the moon. The Snanai'muQ, who are closely related to the Lku'ñgEn, and whose customs are very much the same as those of the Lku'ñgEn, worship the sun and pray to him. Traces of sun-worship may be found among the Lku'ñgEn in the custom of young girls and boys avoiding to eat until the sun is high up in the sky, in the sī'ōua offering her prayers towards sunrise, and in the regulation that novices and menstruating girls must go homeward in a direction following the course of the sun.

Animism underlies the religious ideas of the Lku'ñgEn, as well as those of all other North American Indians. Animals are endowed with superhuman powers, and inanimate objects are considered animate. Trees are considered transformed men. The creaking of the limbs is their voice. Animals, as well as the spirits of inanimate objects, but principally the former, can become the genii of men, who thus acquire supernatural powers. A peculiar conception is what is called *stlā'lEk·am*. This is as well the protective genius of a man, as a supernatural being whose power is directed against a man. Therefore it seems to express the relation of man to supernatural powers. Certain occupations or actions are forbidden to mourners, parents of new-born children, menstruating women, shamans, novices of secret societies, and dancers, because certain objects are *stlā'lEk·am* against them. The door and the earth, as being *stlā'lEk·am*, were mentioned in a foregoing paragraph. In dreams the soul leaves the body and wanders all over the world. The soul after death retains human shape and becomes a ghost. Shamans are able to see ghosts. Their touch causes sickness. They make those who have not regarded the regulations regarding food and work mad. Their touch paralyses man. When one feels afraid, being alone in the woods or in the dark, it is a sign that a ghost is near. They know who is going to die, and approach the villages early in the evening to take the soul of the dying person away. In order to drive the ghosts away the people cry *q, q!* beat the walls of the houses with sticks, and burn *Peucedanum leiocarpum*, Nutt., to drive them off. Some people believe individually that the soul of a man may be born again in his grandchild.

There are two classes of conjurers or shamans, the higher order being that of the *sQunä'am*, the lower that of the *sī'ōua*. The sī'ōua is generally a woman. It seems that her art is not acquired by intercourse with spirits, but it is taught. The principal function of the sī'ōua is that of appeasing hostile powers. It is believed that certain objects are hostile to man, or to man in certain conditions; for instance, to mourners, to menstruating women, to shamans, dancers, and novices of secret societies. These hostile powers may be appeased by the sī'ōua bespeaking them in a sacred language. The words of this language are handed down from one sī'ōua to the other, and heavy payments are exacted for instruction. There is not one sī'ōua left among the Lku'ñgEn, and my endeavours to learn any of the words of this language were consequently vain. The same means are used for endowing men or parts of the body, weapons, &c., with special power. This is called 'to give a name to an object' (for instance, *k'cī'tEs*, to give a name to the door, see p. 579), *nāsE'nEtEs*, or *k'cE'nEtEs*, to give a name to a man). The sī'ōua gives a name to the body (*nanahē'kustes*) to enable man to go easy, that means, to be able-bodied and strong. She invokes good fortune by going down to the beach at the time of sunrise and at the time of sunset, and, looking eastward, she dips her hands into the water, sprinkles a few drops upward, and blows a few puffs of air eastward. She is able to cure such diseases as are not due to the absence of the soul from the body. She rubs the sick person with cedar-bark, paints his face red, and blows some puffs of air upward. The sick one must fast all day, and at sunset she goes to the beach and talks towards sunrise in the sacred language. She is applied to by women who desire to bear children. They are given decoctions of wasps' nests and flies, as both lay many eggs. She also helps women to bring about abortion. For this purpose she kneads the belly of the woman in the second month of pregnancy. Her hands and the skin of the belly are made more pliable by means of tallow and grease. She also lets the woman lift heavy loads and eat leaves of a species of Carex, which have very sharp edges, that they may cut the embryo (see p. 577). For a love-charm she rubs girls with cedar-bark, and in the same way she restores the lost affection of a husband. When a man has been absent for a long time on a hunting expedition, and his friends fear that some accident may have befallen him, they call the sī'ōua, who stretches out her hands to where he has gone. If, on doing so, she feels a pressure on her breast, something has happened to the absent man; if she does not feel anything he is safe. All these practices of the sī'ōua are accompanied by incantations in her peculiar language and by dances and dancing songs. In dancing she holds her arms on both sides of the body, the elbows not far from the waist, the hands upright, the palms forward, approximately on a level with the head. Her hands are trembling while she dances. I collected one of these songs, sung by the Lku'ñgEn sīōua, but the words being in the Cowitchin language:—



The Lku'ñgEn equivalent of these words is: *K'u'nEttsEQ qtEñgē'k·En*, *i.e.*, see her (the sī'ōua) now going along.

The *sQunä'am*, the shaman, is more powerful than the sī'ōua. He is able to see the soul and to catch it when it has left the body and its owner is sick. A man becomes a sQunä'am by intercourse with supernatural powers. Only a youth who has never touched a woman, or a virgin, both being called *tc'ē'its*, can become shamans. After having had sexual intercourse, men as well as women become *t'k·ē'el*, *i.e.*, weak, incapable of gaining supernatural powers. The faculty cannot be regained by subsequent fasting and abstinence. The novice goes into the woods, where he bathes and cleans himself with cedar-branches (*k'oatcā'set*). He sleeps in the woods until he dreams of his guardian spirit, who bestows supernatural power upon him. This spirit is called the *tl'k·'ā'yin*, and corresponds to what is known as the *tamanowus* in the Chinook jargon, and 'medicine' east of the Rocky Mountains. Generally the *tl'k·'ā'yin* is an animal, for instance a bear, a wolf, or a mink. This animal is henceforth, as it were, a relation of the shaman, and helps him whenever he is in need of help. He is not allowed to speak about his *tl'k·'ā'yin*, not even to say what shape it has. When he returns from the woods the shaman is able to cure diseases, to see and to catch souls, &c. The best time of the day for curing disease is at nightfall. A number of people are invited to attend the ceremonies. The patient is deposited near the fire, the guests sit around him. Then they begin to sing and beat time with sticks. The shaman (who uses no rattle) has a cup of water standing next to him. He takes a mouthful, blows it into his hands, and sprinkles it over the sick person. Then he applies his mouth to the place where the disease is supposed to be and sucks at it. As soon as he has finished sucking, he produces a piece of deer-skin or the like, as though he had extracted it from the body, and which is supposed to have produced the sickness. If the soul of the sick person is supposed to be absent from the body the shaman sends his *tl'k·'ā'yin* (not his soul) in search. The *tl'k·'ā'yin* brings it, and then the shaman takes it and puts it on the vertex of the patient, whence it returns into his body. These performances are accompanied by a dance of the shaman. Before the dance the sī'ōua must 'give name to the earth,' which else would swallow the shaman. When acting as a conjurer for sick persons he must keep away from his wife, as else his powers might be interfered with. He never treats members of his own family, but engages another shaman for this purpose. It is believed that he cannot cure his own relatives. Rich persons sometimes engage a shaman to look after their welfare.

The shaman is able to harm a person as well as to cure him. He causes sickness by throwing a piece of deer-skin, or a loop made of a thong, on to his enemy. If someone has an enemy whom he wants to harm he endeavours to obtain some of his saliva, perspiration, or hair, the latter being the most powerful means, particularly when taken from the nape or from the crown of the head. This he gives to the shaman without saying to whom it belongs, and pays him for bewitching it. I did not learn the method of treating these excretions of the enemy's body, except that the performance takes place at nighttime. Then the man to whom the saliva, perspiration, or hair belongs undergoes cramps and fits. The sQunä'am, as well as the sī'ōua, may take the soul of an enemy and shoot it with arrows or with a gun, and thus kill their enemy. If a man is 'too proud and insolent' the doctor will harm him by simply looking at him. It is told of one shaman that he made people sick by giving them charred human bones to eat.

The third function of the shaman is to detect evil-doers, particularly thieves, and enemies who made a person sick by employing a shaman. They solve this task by the help of their tl'k·ā'yin. When it is assumed or proved that a man has caused the sickness of another the latter or his relatives may kill the evil-doer.

II. THE NOOTKA.

Our knowledge of the Nootka is not so deficient as that of most other tribes of British Columbia, as their customs have been described very fully by G. M. Sproat in his book 'Scenes and Studies of Savage Life' (London, 1868). The descriptions given in the book are lively and trustworthy, so far as they are founded upon the author's own observations; but unfortunately he has not always referred to his informants, so that it is impossible to distinguish what he has observed himself from what he has learnt from hearsay. The linguistic part of his book is taken almost bodily from an anonymous work by a Catholic missionary, named Knipping, 'Some Account of the Tahkaht Language as spoken by several tribes on the Western Coast of Vancouver Island' (London, 1868), which latter book has remained almost unknown. The power of observation exhibited in the descriptions of the author, however, is not to be depreciated. I confine myself in my description to recording the new facts that I have observed or learnt by inquiries among the older Indians.

The Nootka consist of twenty-two tribes, the names of which are derived from the names of the districts they inhabit. The tribes speak closely allied dialects of the same language. North of Barclay Sound the changes of dialect are so gradual that it is impossible to draw any distinct lines between them. It seems that the dialects of Cape Flattery and of Nitinat Sound are also very closely affiliated. Thus it appears that the tribes of the Nootka stock may be divided into three groups speaking distinct dialects, but all intelligible to each other. The following is a list of these twenty-two tribes:—

I.	1. Tlā′asath=outside people	Cape Flattery.
	2. Patcinā′ath	San Juan Harbour.
	3. Ni′tinath	Nitinat Sound.
II.	4. Hō′aiath	Barclay Sound.
	5. Hāutcu′k·tlēs′ath	
	6. Ekū′lath=bushes on hill people	
	7. Hatcā′ath	
	8. Ts′ēcā′ath	
	9. Tōk′oā′ath	
	10. Hōpetcisā′th	
III.	11. Yutlū′lath	Northern entrance Barclay Sound.
	12. Tlaō′kwiath	Clayoquaht Sound.
	13. K·eltsmā′ath=rhubarb people	
	14. A′hausath	
	15. Mā′nōosath = houses on spit people.	
	16. He′ckwīath	Nootka Sound.
	17. Mō′atcath	
	18. Mō′tclath	
	19. Nutcā′tlath	
	20. Ē′hatisath	
	21. Kayō′kath	North of Nootka Sound.
	22. To′ē′k·tlisath=large cut in bay people. (Tlahosath).	

I have given the last name in parentheses, as even on special inquiry I did not hear anything about this tribe, which is the last in Sproat's list, but is not contained in that of Knipping. The Ēkū'lath and Hatcā'ath are not contained in the former lists. The Ēkū'lath have greatly decreased in numbers and therefore joined the Ts'ēcā'ath; the Hacā'ath have become extinct. The tribes of Barclay Sound claim that the Hōpetcisā'th did not belong originally to the Nootka people, but that they were assimilated when the Ts'ēcā'ath migrated up Alberni Channel and settled in the upper part of this region, which event is said to have taken place less than a century ago. The Hōpetcisā'th, who at that time inhabited the head of Alberni Channel and Sproat Lake, are said to have spoken the Nanaimo language. I have tried to find any traces of that language in local names, but have been unsuccessful. It is true that the natives do not understand the meaning of most of the names of places; but, on the other hand, I have not found any that can be referred to the Nanaimo language. A number of men of the age of about fifty years affirm that their grandfathers did not know the Nootka language, but spoke Nanaimo, and that their fathers still knew a number of words of the old language. It may be mentioned in this connection that the vocabulary contains a few words borrowed from the Nanaimo. The traditions and totems of the Hōpetcisā'th bear out their claim that they originally lived in the interior of the island, and did not visit the mouth of Barclay Sound (see below). I have not succeeded in finding any evidence of this change of language except the unanimous assertions of the natives.

The single tribes are subdivided into septs, which seem to correspond very closely to the gentes of the Coast Salish, as described in the first section of this report. I obtained lists of the septs of three tribes, the Ts'ēcā'ath, the Hōpetcisā'th, and the Tōk'oā'ath.

I. Septs of the Ts'ēcā'ath.

1. Ts'ēcā'ath	Crest: Wolf.
2. NE'c'asath	,, Whale.
3. NEtcimū'asath	,, Thunder-bird.
4. WaninEa'th	,, Snake.
5. Mā'ktl'aiath	,, Crab.
6. Tla'sEnūesath	,, Aia'tlk·ē.
7. Ha'mēyisath	,, Sea-otter.
8. Ku'tssEmhaath	,, Tc'ēnē'ath.
9. Kuai'ath	,, Whale and man.

II. Septs of the Hōpetcisā'th. Crest: Bear, wolf.

1. Mō'hotl'ath.
2. Tl'i'kutath.
3. Tsō'mōs'ath.

III. Septs of the Tok'oā'ath.

1. Tok'oā'ath.
2. Maa'kōath.
3. Wā'stsanEk.
4. Tō'tak·amayaath.
5. Tsa'k·tsak·oath.
6. Mu'ktciath.
7. Tuckis'a'th.
8. Kōhatsōath.
9. Tc'ē'natc'aath.
10. MEtstō'asath.
11. Tcō'māath.

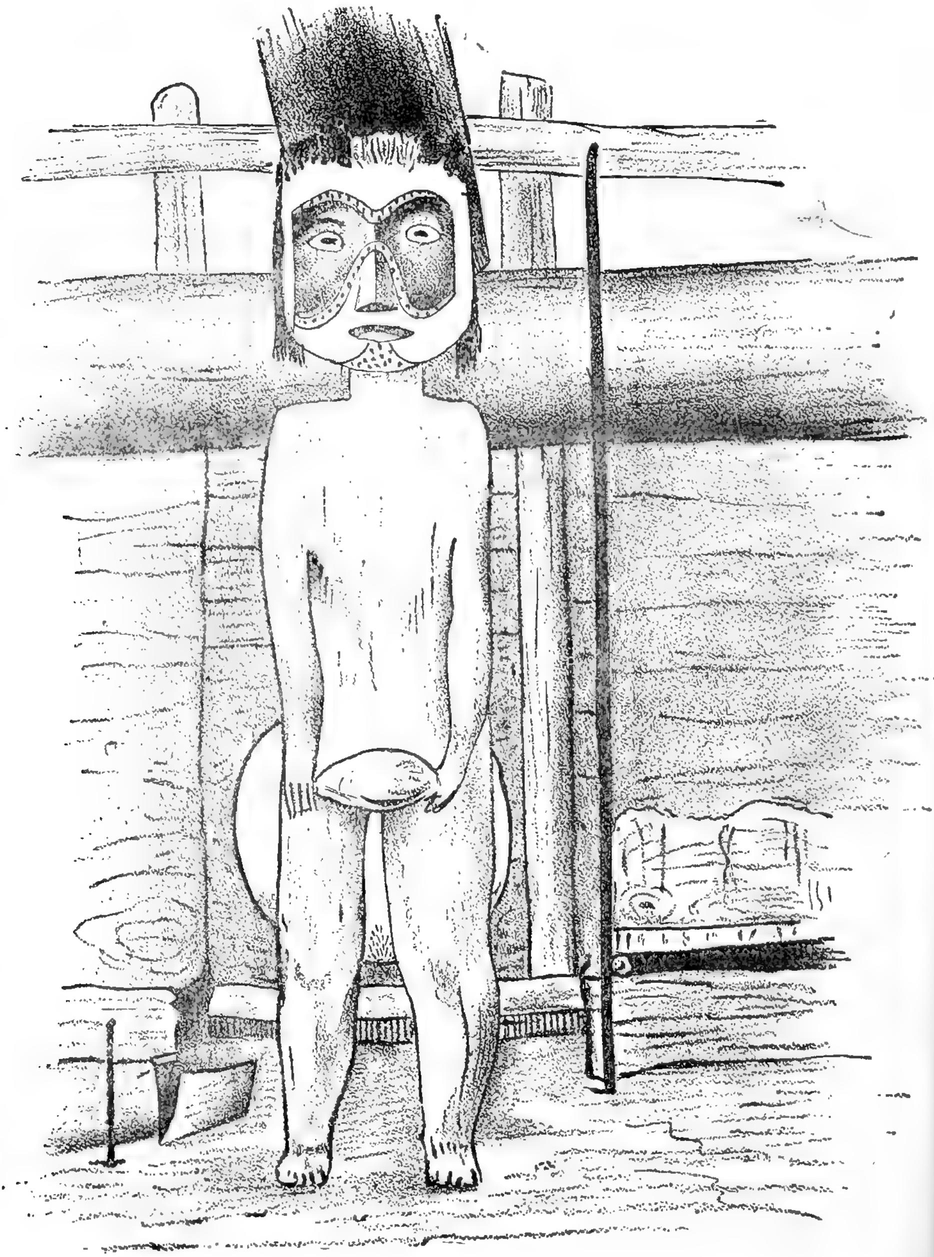
The septs as given here are arranged according to rank, the highest in rank being given first. The whole tribe possesses its territory in common. There seem to be no subdivisions of territory belonging to the various septs. In some instances the tribal boundaries are marked on the coast by some rock of singular shape. Thus a large rock resting on two boulders at Vob Point, Barclay Sound, marks a tribal boundary. It does not seem that artificial monuments were made for this purpose. Each sept has a chief whose authority is restricted to his sept. Only the chief of the sept that is highest in rank exercises some limited authority over the whole tribe. Whatever is found adrift on the sea, as canoes, paddles, &c., in his territory must be delivered to him, and he has to give a present for the same to the finder. Animals found adrift are excluded from this rule. When a sept goes on a hunting expedition the chief, if he has not a sufficient number of canoes, rents them from other septs and pays the crews. The affairs of the tribe are discussed and decided in a council, in which only the chiefs of the septs take part. It is called *īci′mitl.* They decide all important affairs of the tribe, peace and war, marriages of chiefs' daughters and sons, &c. The council also appoint the herald or orator of the tribe (*tsi′k·sak·tl*), whose services are required in all festivals given by the tribal chief and in negotiations with other tribes. The decisions of the council are kept secret. Chiefs alone are allowed to hunt whales and to act as harpooners. This accounts for the observation of Sproat that the right of whaling and the office of harpooner are hereditary (p. 116). Chiefs alone are allowed to give 'potlatches.' Each sept has names that belong exclusively to its members. The chief and the chief's wife of each sept have always a certain name. I give here the chief's names of the Ts'ēcā′ath tribe :—

FIG. 12.—Upright in house of the Ts'ēcā′ath gens.

Sept	Chief	Chief's Wife
1. Ts'ēcā′ath .	. Wīhsusᴇ′nᴇp .	. Ts'ēciā′aks.
2. Nᴇ′c'asath .	. Nᴇ′c'asath .	. Nᴇc'a′saksup.
3. Nᴇtcimū′asath	. Hītatlu′ksois .	. Hō′pkustaak·s.
4. Waninᴇa′th .	. Haīhaiyu′p .	. Hai′nak·autl.
5. Mā′ktl'aiath .	. Haā′yuīh .	. Hayū′poutl.
6. Tla′sᴇnūesath	. T'a′psīt .	. Tc'ēitlᴇ′mᴇk·.
7. Ha′mēyisath .	. T'ēā′tsōis .	. Hai′kwis.
8. Ku′tssᴇmhaath	. Mā′mak·ha′nᴇk .	. Haiā′utl.
9. Kuai′ath .	. Kuai′ath .	. Kuai′aksup.

The chief of the sept, on assuming his position, must take the appropriate name according to the sept to which he may belong; but in course of time, when he gives a great 'potlatch,' he is allowed to assume another name. As soon as the chief's name has thus become

FIG. 13.—Upright in house of the Ts'ēcā'ath gens.

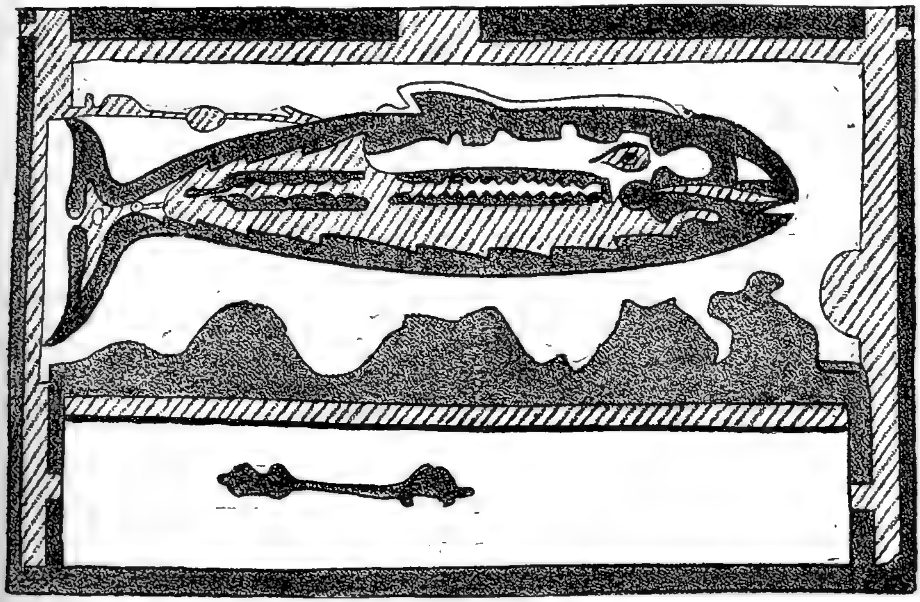


free, another man of the same sept will take it up. However, no one who does not belong to the chief's family is allowed to assume a chief's name. Thus it happens that any member of the chief's family may, at the time of the chief's demise, have the name of the chief of the sept.

He is then compelled to give it up and take a new name on the accession of the new chief. I give here a few other names that a chief or a member of a chief's family may assume :—

Ts'ēcā'ath	names :	Nenetli'qsenEp.
NE'c'āsath	,,	Nawē'ek.
NEtcimū'asath	,,	Tlusē'sem.
WaninEa'th	,,	Tlemis'oa.
Mā'ktl'aiath	,,	Haynane, Yahkoyap, Teihmatlne, T'ē'yukuit.
		Mamah'is (female).
Kuai'ath	,,	Tlapē'i.

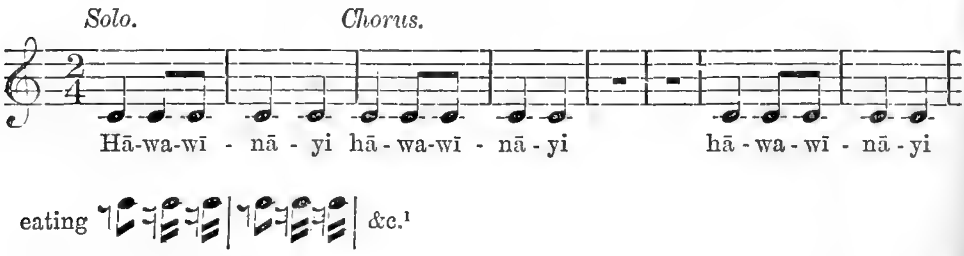
FIG. 14.—Painting on house of the NE'c'āsath chief.



It is stated that the Ts'ēcā'ath had the privilege to hunt fur-seals. Each sept has an animal for its crest, as shown in the list of septs of the Ts'ēcā'ath, to the names of which that of their crest has been added. The crests do not play by far so important a part as in the social institutions of the Kwakiutl and of the other tribes living farther north. The crest is only used in the 'potlatches' and in the secret society Tsā'yēk·, as will be described later on. We find, however, paintings and carvings on many houses which are in the same way connected with the legends of the sept, as was described in my former report when treating of the Kwakiutl. Fig. 12 shows one of the uprights in the house belonging to the chief of the Ts'ēcā'ath. It represents the fabulous ancestor of this sept, who is said to have descended from heaven. Fig. 13 shows another support of the main beam of the same house. It represents a man who is about to hurl a stone, a game which is always played at the beginning of a 'potlatch.' The whale shown in fig. 14 is painted on few boards on the outside of a house belonging to a chief of the NE'c'āsath sept.

The Potlatch.

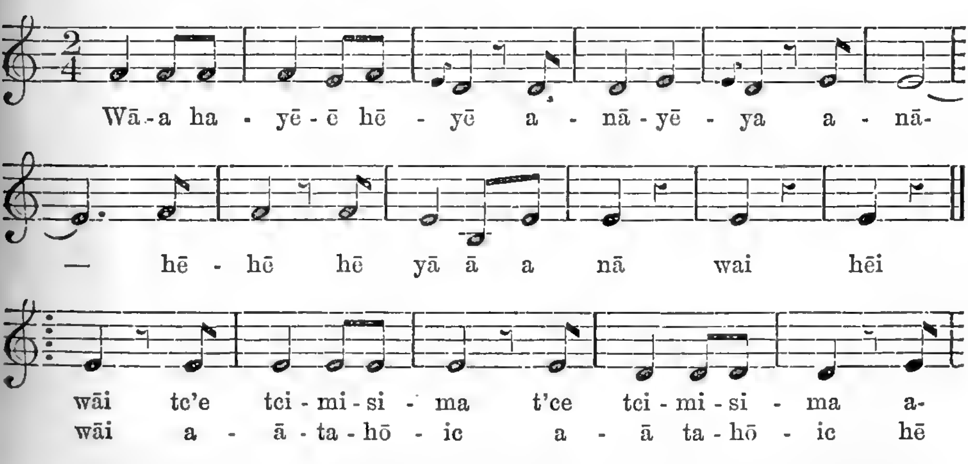
The custom of giving great feasts, at which a large amount of property is distributed, is common to the Nootka and all their neighbours. The principle underlying the potlatch is that each man who has received a present becomes, to double the amount he received, the debtor of the giver. Potlatches are celebrated at all important events. The purchase-money of a wife belongs to this class also, as it is returned to the purchaser after a certain lapse of time (see below). After the death of a chief, his heir is not installed in his dignity until he has given a great potlatch. If he is to be the chief of the whole tribe the neighbouring tribes are invited to take part in the potlatch. The taking of a name and that of a dance (see p. 600) are also celebrated by a potlatch. This custom is practically the same among all the tribes of the north-west coast. When a chief has to give a great potlatch to a neighbouring tribe, he announces his intention, and the tribe resolve in council when the festival is to be given. A messenger is sent out to give notice of the intention of the chief to hold a potlatch at the agreed time. When all preparations have been finished, and the time has come, another messenger, called *ia'tsetl*, is sent out to invite the guests to come to the festival. The guests come in their canoes, and when not far from the village they halt and dress up at their nicest, smearing their faces with tallow and then painting with red colour. Then the canoes proceed to the village in grand procession, their bows being abreast. At this time certain songs are sung, each tribe having its own song. When they are seen to approach, the tribe who have invited them go down to the beach. The chief's son or daughter is attired in the dress and mask of the crest animal of the sept, and performs a dance in honour of the guests. The *ia'tsetl* next calls the name of the head chief of the visitors, and he comes ashore. Then the others are called according to rank. They are led into the chief's house, after having received one or two blankets when landing. On entering the house they are also given a few blankets. The guests are feasted first by the chief and then by all other members of the tribe who can afford it. Finally, after a number of feasts have been given, the chief prepares for the potlatch, and under great ceremonies and dances the blankets are distributed among the guests, each receiving according to his rank. At the potlatch certain songs are sung. Each chief has a song of his own that is only sung at his feasts. Here is the song of the Ts'ēcā'ath sept, sung when its chief gives a potlatch :—



[1] The batons used in beating time are raised at the heavy parts of the bar: this accounts for the peculiar rhythm given above.

I.e., Ha! Boats are coming. He will give again blankets to the chiefs among the coming boats. He will give blankets.

After the death of a chief this song is sung; but after that the people are forbidden to use it for one year, when the potlatch is given in which the succeeding chief assumes his dignity. Among the gifts bestowed at a potlatch is the right to perform certain non-religious dances that are only danced at such feasts. In such cases the original owner retains the right to the dance, although he has given the same right to a friend. In this respect the customs of the Nootka differ from those of the Kwakiutl, among whom a man who gives away the right to perform a dance loses the right to perform the same. I will give an instance showing the way in which a certain dance may be passed from tribe to tribe. The Kayō'kath have a tradition that at one time their chief when hunting met a man who had descended from heaven beside a small lake on one of the islands near Kayō'kath. The man had ten mouths, each of different shape, which he showed in succession. He asked the chief whether he desired to have always a plentiful supply of salmon. The latter replied that he did not need any salmon, as his people used to gather an abundant supply of mussels, which had red flesh as well as the salmon, and that consequently he had no use for the latter. Then the stranger made the pond dry up, and ever since that time there have been no salmon at Kayō'kath. The chief, in memory of this encounter, danced in potlatches with the mask representing the many-mouthed being. He dances behind a curtain, only the upper part of his body being visible; now and then he will stoop down, so as to become quite invisible, and then reappear with another mouth. Here is his song:—[1]

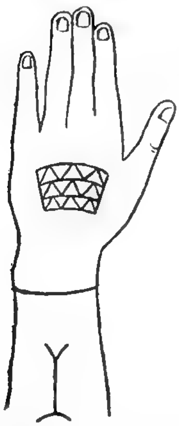


[1] I heard the song sung by a very poor singer. The rhythms are probably correct, the intervals very doubtful.

I.e., Get ready, all you tribes. He says my property will be rushed down the river.

The chief of the Kayō'kath gave this song to the Ahau'sath at a potlatch, who, in their turn, gave it as a present to the Ts'ēcā'ath chief. It seems that the Nootka do not use dancing-aprons as the Kwakiutl do. In the potlatch dances men, women, and children dance the same dances. It is stated that the Ahau'sath at one time made different dances for men, women, and children, but this was an exceptional experiment. In former times the privilege of performing a certain dance was rigidly guarded, and many wars were raged against tribes who performed a dance to which they had no right.

Fig. 15.—Nootka Tattooing.



Some persons tattoo their crest on their bodies. An old man of the Hōpetcisā'th tribe, for instance, has a wolf tattooed on his belly and breast. The hands of women and men are frequently tattooed. I observed one man who had a line tattooed connecting both eyebrows. The same person had the upper half of his moustache pulled out. It is stated, however, that these practices have been recently introduced (fig. 15).

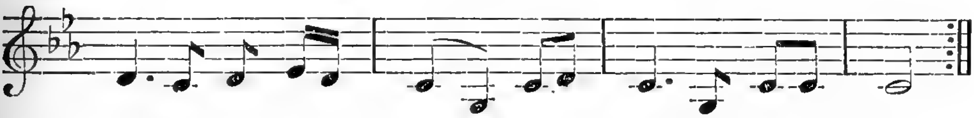
I may remark in this place that the copper plates which play so important a part in the customs of the northern tribes are not used by the Nootka.

Games.

The games of the Nootka are identical with those of the neighbouring tribes. A favourite game is played with hoops, which are rolled over the ground. Then a spear is thrown at them, which must pass through the hoop (*nūtnū'tc*). A guessing game is frequently played between two parties, who sit in two rows opposite each other. One party hides a stone, the men passing it from hand to hand. The other party has to guess where it is (*t'ēt'ētsEk·tlis*). The following song, although belonging originally to Cape Flattery, is used all along the west coast of Vancouver Island in playing the game *lehal*:—

I.e., I, Nacwitōah, have missed it.

Lullaby.



I.e., See the mink there diving between the islands.

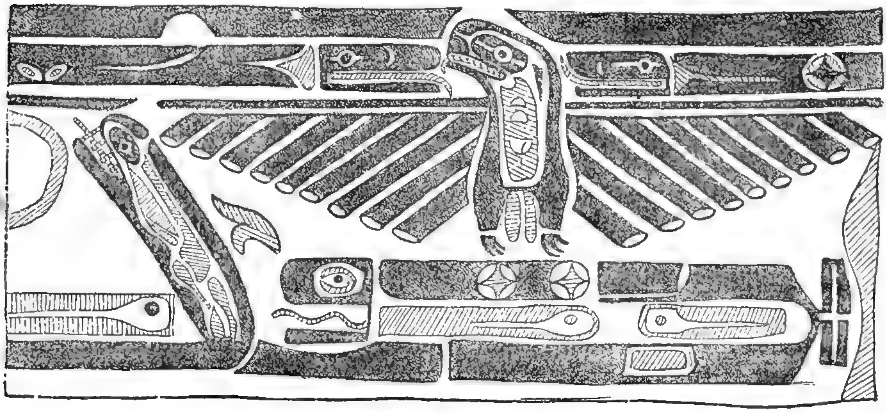
Customs referring to Birth, Puberty, Marriage, and Death.

The customs referring to birth seem to be almost the same as those of the Lku'ñgEn. During the period of pregnancy the woman must not wear bracelets and anklets. After the child is born the father must clean himself by bathing in a pond. For four days he is forbidden to go in a canoe. He and also the young mother are forbidden to partake of fresh food. The former must speak in whispers only. The infant's head is flattened in a cradle, which is very much like that of the Lku'ñgEn in construction. The cradle is either made of wood or platied of strips of cedar-bark. Immediately after birth the eyebrows of the babe are pushed upward, its belly is pressed forward, and the calves of the leg are squeezed from the ankles upward. All these manipulations are believed to improve the appearance of the child. It is believed that the pressing of the eyebrows will give them the peculiar shape that may be seen in all carvings of the Indians of the North Pacific coast. The squeezing of the legs is intended to produce slim ankles. It is, however, probable that these manipulations have no lasting effect.

Numerous regulations refer to the birth of twins. The parents of twins must build a small hut in the woods, far from the village. There they have to stay two years. The father must continue to clean himself by bathing in ponds for a whole year, and must keep his face painted red. While bathing he sings certain songs that are only used on this occasion. Both parents must keep away from the people. They must not eat, or even touch, fresh food, particularly salmon. Wooden images and masks, representing birds and fish, are placed around the hut, and others, representing fish near the river, on the bank of which the hut stands. The object of these masks is to invite all birds and fish to come and see the twins, and to be friendly to them. They are in constant danger of being carried away by spirits, and the masks and images—or rather the animals which they represent—will avert this danger. The twins are believed to be in some way related to salmon, although they are not considered identical with them, as is the case among the Kwakiutl. The father's song which he sings when cleaning himself is an invitation for the salmon to come, and is sung in their praise. On hearing this song, and seeing the images and masks, the salmon are believed to come in great numbers to see the twins. Therefore the birth of twins is believed to indicate a good salmon year. If the salmon should fail to come in large numbers it is considered proof that the children will soon die. Twins are forbidden to catch salmon, nor must they eat or handle fresh salmon. They must not go sealing, as the seals would attack them. They have the power to make good and bad weather. They produce rain by painting their faces with black colour and then washing them, or by merely shaking their heads.

I obtained a comparatively full account of customs practised at the time when the girl reaches puberty (see Sproat, p. 94). She is placed on the platform of the house, opposite the door, and the whole tribe are invited to take part in the ceremonies. A number of men and women are engaged to sing and dance on this occasion, and are paid for their

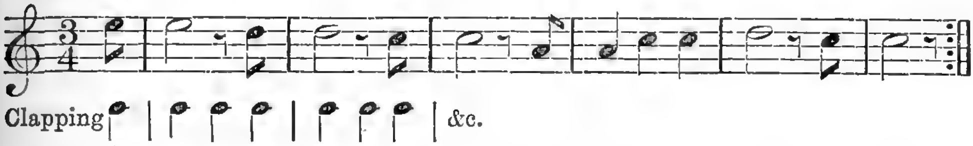
FIG. 16.—Screen with painting representing Thunder-bird and Whale.



services. While these songs, which are called *'ta'mā*, are sung, a man in the attire of a thunder-bird stands on each side of the girl. The dresses of these men consist each of a large mask, to which a complete dress, set with feathers and having two wings, is attached. The dancers wear no masks. Then eight men take each a dish, go down to the river, and fetch water, with which they return to the house. In doing so they must move in a circle, having their left hand on the inner side of the circle. Then they pour the water on the girl's feet and return to the river, still moving in a circle, their left hand being on the inner side. As soon as this performance is over, a screen, painted with images of thunder-birds (fig. 16),[1] is set upon the platform in front of the girl, so as to hide her completely. On both sides mats are hung up, and thus a small room is provided for the girl, who has to stay here hidden from the sight of men for a number of days. During this period she is always attended by a number of girls and women. According to Sproat's statement, she is not allowed to see the sun or a fire. According to my informant, she must be guarded against seeing anything ugly and against

[1] A second screen with a symmetrical drawing adjoins the left side of the one figured above.

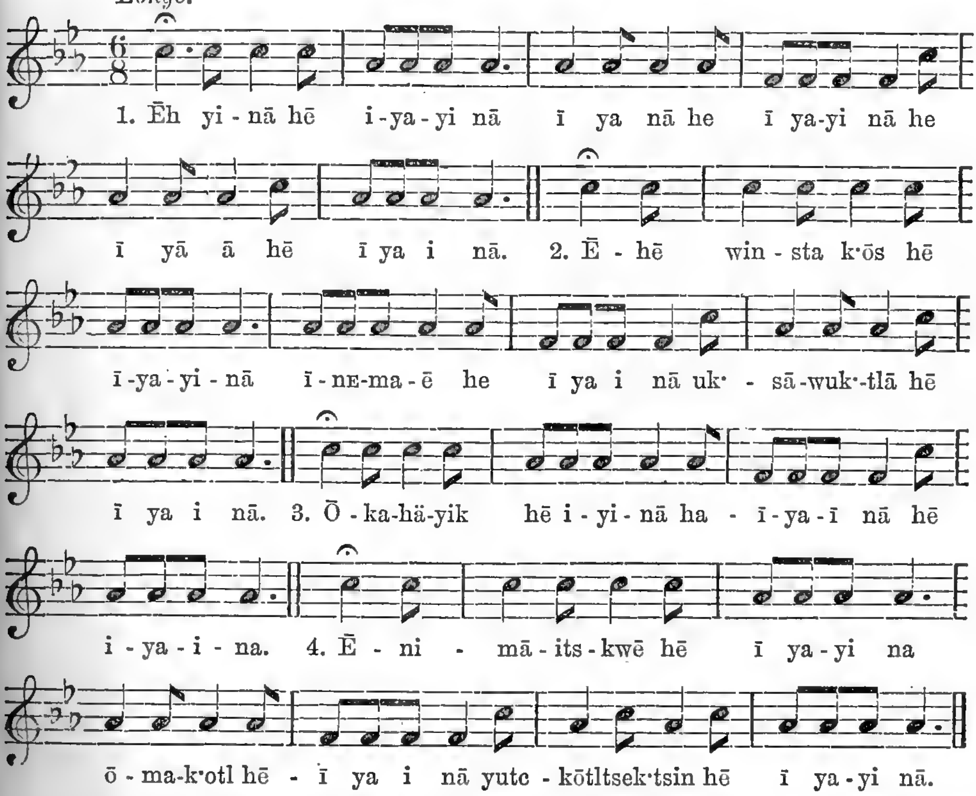
seeing men. During the time of her seclusion she wears no shirt, and is forbidden to move and to lie down, but must always sit in a squatting position. She must avoid touching her hair, but scratch her head with a comb or with a piece of bone, provided for the purpose. Neither is she allowed to scratch her body, as it is believed that each scratch would leave a scar. While she is hidden behind her screen the festival continues. Sometimes they even begin the Tlokoa'la (see below, p. 599). Here are two songs which are sung on these occasions:—



i - ä	i - ä	i - ä	a - i - ya i	nä	i - ā
Kaq - cī	ka - mâ'	tla - tlä	kui-tutl-sya i -	nä	i - ā
O - ō	tu - tläh	as - äh	as ō - uc pa -	tcätl	i - ā
Hi - nē	tsutl - k·ät	at - lä	ya hōqtlak·tsak·k·äs		i - ā
An - ā	sa - k·ō	tca - kōp	u - atl-k·atha - tläh		i - ā
i - ä	i - ä	i - ä	a - i - ya i -	nä	i - ā.

I.e., I had a bad dream last night. I dreamt my husband took a second wife. Then I packed my little basket and [?], and I said before I left, There are plenty of men. Thus I dreamt.

Longe.



I.e., I wish I had my face at a girl's bosom. I should feel good. Oh, dead! Yes, your face is large enough for a thing that is never satisfied.

During her seclusion in her small room the girl fasts, and for eight months after reaching maturity she is forbidden to eat any fresh food, particularly salmon. On the fourth day after her first menses she puts on a peculiar head-ornament, which she must wear during each of her first eight menses for four days. During these months she must eat by herself, and use a cup and dish of her own. These latter regulations have to be observed by all women during menstruation. After reaching maturity girls must bathe regularly in the woods. They are forbidden to bathe near the village where the men might happen to pass by.

The marriage ceremonies have been so well described by Sproat that I confine myself to giving a few additional data, referring to the marriage of persons of the rank of chiefs. When a young man wishes to marry a certain girl his father sends messengers to the girl's father to ask his consent. At first it is not given, and the messengers are sent again and again, until the consent of the girl's father is obtained. The messengers do not enter the house of the latter, but deliver their message outside the door. At last the girl's father consents, and then the messengers plant a staff into the ground close to the door. A blanket is wrapped around the staff, which is made to represent a wolf, a bird, or a man. Bird's down is strewn on the top of the figure. On the following day the girl's father sends back this figure with a large quantity of food, and the message that the young man may come and marry his daughter. The young man's father invites all his relatives, and gives a feast of the food sent by the girl's father. On the same night whistles imitating wolves' voices are blown in the houses and on the street. I do not know whether the origin of these whistles is kept a secret from the people, but think it probable that only the members of the Tlokoa'la (see below) know about it. On the following morning a platform is built by covering two boats with planks. The young men of the groom's family paddle away from the shore and then return dancing. The groom himself dances in the mask and dress of the thunder-bird, one of his relatives in that of a whale. All the dancers are painted, and have their hair strewn with feathers. They land, and a man dressed up like a wolf is the first to go ashore. A number of men carrying blankets follow him. When the groom's party is heard to approach, the bride's father calls upon a number of strong men from among his family, and places them in front of his house. When the other party arrives and prepares to enter the house the opposite party drives them back. This is done four times. Then they are allowed to enter; the leader throws down the wolf's mask in the house of the bride's father, and the blankets which his followers carry are piled up on top of it. The bride's friends next prepare games, which are played out of doors, weather permitting; else they are held indoors. First, twelve men stand in two rows of six each, one opposite the other. They carry torches of bundles of cedar-bark, so that there is a narrow lane left between the lights of the opposite rows. The groom's father and one or two of his uncles must pass through this lane. Next two long poles are tied together at their points, and put up vertically. A pulley is attached to the joint, a thin rope is passed through it, and a small carved wooden whale is suspended from it. The feet of the two poles stand about six feet apart, and the joint is about twelve feet high. The carved figure hangs so high that it requires a good jump to reach it. One of the bride's relatives holds the free end of the line attached to the carved figure. The groom's relatives try to catch the carved figure, which, however, is pulled up by the man holding the rope as soon as anyone tries to take hold of it. The man who finally succeeds in grasping it receives a few blankets from the girl's father. Then a horizontal pole is fastened at one end, swinging freely at the other. The men belonging to the groom's party have to try to walk down to the swinging end, and whoever succeeds receives blankets from the girl's father. Heavy weights are lifted; they try who is the best jumper. A blanket with a hole in the centre is hung up, and men walk up to it blindfolded from a distance of about twenty steps. When they get near it they must point with their fingers towards the blanket, and try to hit the hole. They also climb a pole, on top of which an eagle's nest, or something representing an eagle's nest, is placed. The winner of each game receives a number of blankets from the girl's father. When the games are at an end the groom's father distributes blankets among the other party. Now they are allowed to take the girl with them. A man, dressed up as a wolf or a whale, leads the party, and they follow him in Indian file, going around in a circle, the left hand being on the inner side (that is, opposite to the course of the sun). They take the girl to their house, and give a great feast. After a while the bride's father gives a feast to his son-in-law, who returns it after a short time, and thus they continue to feast, sometimes for a whole year. Then the bride's relatives return all that was paid to them at the marriage ceremony. The wolf's head which was thrown into the girl's house is always returned at once.

The child belongs to that sept which is considered the nobler. If, for instance, the mother is a Ts'ēcā'ath, the father a Kuai'ath, the child will be a Ts'ēcā'ath. Cousins and second cousins are not allowed to intermarry, but there is no restriction against marriages between members of the same gens.

I have nothing of importance to add to Sproat's description of the mortuary ceremonies, except that the names of the deceased must not be mentioned. Mourners cut their hair short; but while among the Lku'ñgEn the nearer relatives cut it shorter than the others, among the Nootka all cut it equally short. The women wail early in the morning.

Religion and Shamanism.

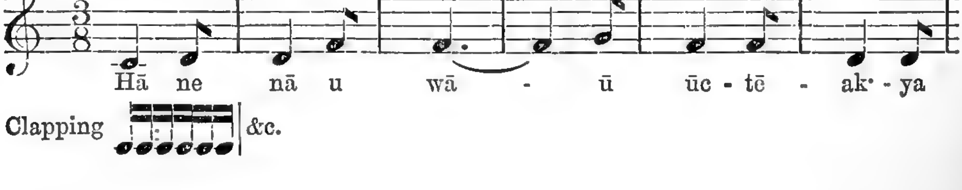
The mythology of the Nootka refers to two men who descended from heaven and transformed the semi-human beings of the ancient world into men and animals.[1] They are called Kwēka'stEcsEp, *i.e.*, the transformers, and are said to have taught men to worship the deity in heaven. The name of the deity is kept a profound secret from the common people. Only chiefs are allowed to pray to him, and the dying chief tells the name, which is Kā'tse (*i.e.*, the grandchild) to his heir, and teaches him how to pray to the deity. No offerings are made to Kā'tse; he is only prayed to. In a tradition of the Nootka it is stated that a boy prayed to a being in heaven called Ciciklē, who is probably identical with Kā'tse. The boy is described as praying, his arms being thrown upward. Ordinarily the Nootka pray to the sun and the moon for health, or, as the expression in their language is, for life and the well-being of their children. The moon especially is asked for food and for good luck in hunting. Both are believed to have human shape. Besides these higher deities, the Nootka believe the whole of nature to be animated. The rainbow was originally a man, and still retains much of his power.

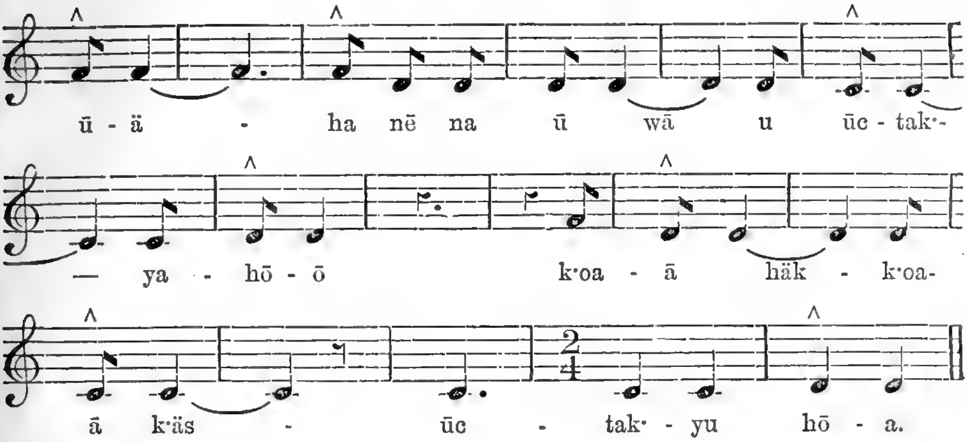
[1] See Swan, *The Indians of Cape Flattery*, p. 64.

Wolves are considered powerful beings, whose friendship is sought for and whose anger is dreaded. Therefore chiefs are not allowed to kill them. Especially is this the case with the Hōpetcisā′th chiefs, whose crest is the wolf. The real meaning of this belief will become clear when taken in connection with the Tlōkoa′la rites and traditions. It is believed that the wolves drive the deer towards the Hōpetcisā′th, more particularly to the Ts'ō′mos hunters.

The world is believed to be a round disc which is supported by a pole. Eclipses of sun and moon are produced by the 'door of heaven' swallowing them. This door of heaven occurs frequently in tales, and threatens to swallow any person who intends to pay a visit to the deity in heaven. Attempts are made during eclipses to free the sun or the moon by making noise and by burning food on the beach. Thunder is produced by the flapping of the wings of the thunder-bird Tū′tutc, the lightning by his belt, the snake Hahē′k·toyek·, which he casts down upon the earth. The fortunate finder of a bone of the Hahē′k·toyek· possesses one of the most powerful charms the natives know of.

The soul has the shape of a tiny man; its seat is the crown of the head. As long as it stands erect the person to whom it belongs is hale and well; but when it loses its upright position for any reason its owner loses his senses. The soul is capable of leaving the body; then the owner grows sick, and if the soul is not speedily restored he must die. To restore it the higher class of shamans called K·ok·oā′tsmaah (soul-workers) are summoned. I cannot give a satisfactory explanation of the methods employed to gain this power, as the natives proved to be rather reticent in regard to these subjects, as well as many others that are among the most interesting to ethnologists. The K·ok·oā′tsmaah seems to acquire his power by fasting and cleaning himself in ponds, as is the custom among all tribes of this region. He catches the wandering soul in his hand, and after having shown it to the people restores it to its proper place by laying it on the top of the head of the sick person. I heard several Indians maintain that they had seen the soul caught by the shaman, who let it march up and down on a white blanket. The second class of shamans are the Ucta′k·yu, *i.e.*, the workers. I did not hear anything regarding an initiation of these shamans by encounters with spirits. It seems that the Tsā′yek· ceremony, which will presently be described, is actually the initiation of the shaman of this class, although, on the other hand, I am not sure that all the members of the Tsā′yek· are considered to have the power of curing diseases. These shamans are capable of curing all diseases, except such as are caused by the soul leaving the body. The cause of sickness is either what is called 'mā′yatlē,' *i.e.*, sickness flying about in the shape of an insect and entering the body without some enemy being the cause of it; or the sick person has been struck by sickness thrown by a hostile shaman, which is called 'mᴇnu′qcītl.' Their ordinary method of removing disease is by sucking and singing over the patient. Here is a song which I heard sung by a shaman when curing a sick person:—





During the conjuration they frequently wash their hands and warm them at a fire. It is told as a feat of a female conjurer that she gave her husband something to eat which she promised to extract again from out of his belly; a feat which she is believed to have actually accomplished.

Other shamans are said to be able to suck out arrows, bullets, and the like. In cases of fractures of bones they give the patient a mixture of ground human bones to drink, or spread it over the fractured place. They treat abscesses by massage or kneading, and open them and take out the matter. If the fish do not come in time, and the Indians are in want of food, a shaman makes an image representing a swimming fish, and puts it into the water in the direction in which the fish used to come, and it is believed that this means will induce them to come at once. He prays at the same time for the fish to come, and calls them.

Every man, upon reaching maturity, may obtain a charm by continued fasting and bathing in ponds. When trying to ascertain how far back historical tradition extends, I was told the following by Tlutisim, a man about thirty years old, belonging to the NEtcimū′asath sept: His great-grandfather's grandfather—*i.e.*, five generations back—sat one night on his bed resting, but not sleeping, as hunters will do. At midnight he heard someone singing on the beach. He went out to see who was there, and discovered a number of Ya′ē—a fabulous people living in the woods—landing a sea-lion which they had caught. It is always a foreboding of good luck to see those people. The man ran down to the beach, cried 'hē,' and the Ya′ē were transformed into sea-foam. He gathered it carefully, and hid it. It became his charm, and henceforth he was a great and successful hunter.

After death the soul becomes a ghost, which is called Tci′hā. The world of the souls is in the earth (Hitā′kutla); but chiefs and good men who always prayed to the sun and moon go up to heaven (Hinā′yitl). Those who are killed in war and have had their heads cut off have in after life their faces on their breasts. Drowned persons become spirits called Pu′kmis. They are generally invisible, and linger on the beach. Whenever they appear to men they are seen to shiver for cold. Ghosts have no bones; they produce nightmare by appearing in sleep; to see them causes sickness.

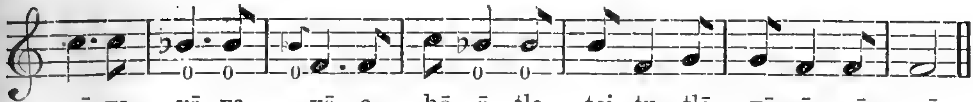
In connection with these beliefs I may mention the following facts which throw some light upon the ideas of the Nootka regarding the relation of soul and body. About twenty years ago a man lost his senses, and attacked another man with a hatchet. The other succeeded in wresting the weapon from his hands. After some time the madman apparently died and was buried, the body being tied up between boards, deposited in the woods, and covered with branches and brushes. After a few days a number of children found him sitting on the beach. He declared that the ghosts had sent him back from their country. The people did not allow him to enter the village until he had bathed and cleansed himself. After a while he was killed by the man whom he had formerly assaulted. As the people continued to be in dread of him, his body was cut to pieces.

A very remarkable method of curing diseases is used when the practices of the shaman prove of no avail. In such case the patient is initiated in the secret society, Tsā'yek·.[1] I obtained the following description of the Tsā'yek· ceremonies: The members of the Tsā'yek· assemble and begin to make a circuit through the whole village, walking in Indian file and in a circle, so that their left hand is on the inner side. Nobody is allowed to laugh while they make their circuit. The following song is sung by the Tsā'yek· society of the Hōpetcisā'th and Ts'ēcā'ath during their circuit through the village:—

I.e., he is not conjurer.

In dancing they hold the first fingers of both hands up, trembling violently. They enter the houses and take the patient and all others who have expressed the wish of becoming Tsā'yek· along, two members of the society taking each novice between them and holding him by his hair, while they continue to shake their other hands. The novice must incline his head forward and shake it, while they continue their circuit. Thus they go from house to house and take along all those who desire to join the society. The circuit finished, they assemble in a house in which for the following days none but members of the Tsā'yek· is allowed. They sing and dance for four days; after these days the novice obtains his cedar-bark ornament. The latter is almost identical with the one described by Swan (p. 74). Small carvings representing the crest of their septs are attached to the front part of their headrings. The dress of the Ucta'k·yū, who is the most important member of the society, is larger than those of any of the other members. The following song is one of those sung by the members during the initiation ceremonies in the house:—

[1] See Swan, *l.c.* p. 73, ff.



The song is repeated *ad infinitum*; in the repetitions quarters are beaten. The dancer jumps at the end of each quarter from one leg to the other. At each jump he lifts one hand and extends the other downward and backward.

I append here a few omens and current beliefs. If there is an irritation in the right side of the nose so that one must sneeze, something good is said of one; if in the left, something bad is said. If one chokes oneself in drinking, the thing one happens to think of will not come true. If one wants to become a great hunter one must not eat of the first game one gets. The first salmon of the season are split on both sides of the backbone, which is then taken out. The head must not be cut off, but remains attached to the backbone. While the head and backbone are thrown into the water, the rest of the fish must be roasted without being cut to pieces. No fresh venison or other meat must be eaten after the salmon begin to run, as else they would stop running for a number of days. The first salmon of the season must not be sold. Salmon are always dried in the houses.

The Tlokoala.

Among the customs of the Nootka their winter dances have always attracted the greatest attention of travellers who came into contact with this people. Good descriptions of the customs connected with these festivals have been given by Sproat, Swan, Jewitt, and Knipping. The meaning of the festivals has, however, remained obscure. This is in part due to the fact that the custom has been borrowed from the Kwakiutl. The name Tlokoala itself, which is a Kwakiutl word, proves its foreign origin. The Tlokoala of the Kwakiutl will be described in the next chapter. Suffice it to say here that the Tlokoala of the Nootka corresponds to the Walas'aqa' or wolf's dance of the Kwakiutl. It has, however, certain other features embodied in it; for instance, the ceremonies of the Mā'tEm dance. The Tlokoala are a secret society, who celebrate their festivals in winter only. They have a chief who is called Yak·syak·stē'itk·. Anyone who wishes to join the Tlokoala can do so, or the society may invite a man to become a member. Then the friends of the person who is to become a member make a collection in his behalf, and turn over the property collected to the chief of the Tlokoala, who distributes it during a great feast among the members. Those who are not Tlokoala are called Wīcta'k·yū, *i.e.*, not being shamans. The Tlokoala is believed to have been instituted by the wolves, the tradition being that a chief's son was taken away by the wolves, who tried to kill him, but, being unsuccessful in their attempts, became his friends and taught him the Tlokoala. They ordered him to teach his people the ceremonies on his return home. Then they carried the young man back to his village. They also asked him to leave some red cedar-bark for their Tlokoala behind, whenever he moved from one place to another; a custom to which the Nootka tribes still adhere. Every new member of the Tlokoala must be initiated by the wolves. At night a pack of wolves—that is, Indians dressed in wolf-skins and wearing wolf-masks—make their appearance, seize the novice, and carry him into the woods. When the wolves are heard outside the village, coming in order to fetch the intending novice, the members of the Tlokoala blacken their faces and sing the following song:—

I.e., Among all tribes is great excitement because I am Tlokoala.

On the following day the wolves return the novice dead, then the Tlokoala have to revive him. The wolves are supposed to have put the magic stone *hä'ina* into his body, which must be removed in order to restore him to life. The body is left outside the house, and two shamans go and remove the hä'ina. It seems that this stone is quartz. The idea is the same as that found among the Kwakiutl, where the Mā'tEm is initiated by means of quartz which is put into his body by the spirit of his dance. The returning novice is called *ū'cīnak*.

After the novices have been restored to life they are painted red and black. Blood is seen to stream from their mouths, and they run at once down to the beach and jump into the water. Soon they are found to drift lifeless on the water. A canoe is sent out and the bodies are gathered in it. As soon as the canoe lands, they all return to life, resort to the dancing house, to which none but the initiated is admitted, and stay there for four days. At night dances are performed in the house, which the whole population is allowed to witness. After the four days are over the novices leave the house, their heads being wound with wreaths of hemlock(?) branches. They go to the river, in which they swim, and after some time are fetched back by a canoe. They are almost exhausted from the exertions they have undergone during the foregoing days. Novices must eat nothing but dried fish and dried berries.

Each Tlokoala lasts four days. It is only celebrated when some member of the tribe gives away a large amount of property to the Tlokoala, the most frequently occurring occasion being the initiation of new members. Sometimes it is celebrated at the time of the ceremonies which are practised when a girl reaches maturity. The house of the man who pays for the Tlokoala seems to be the taboo house of the society. As soon as the Tlokoala begins, the ordinary social organisation of the tribe is suspended—as is also the case among the Kwakiutl. The people arrange themselves in companies or societies which bear the names of the various Nootka tribes, no matter to which tribe and sept the persons actually belong. Each society has festivals of its own, to which members of the other societies are not admitted, although they may be invited. These societies are called *ū'pātl*. Each has a certain song which is sung during their festivities. Here are songs of the Nutcā'tlath and Mö'tclath societies of the Ts'ēcā'ath tribe.

Song of the Nutcā'tlath Society.

Song of the Mö'tclath Society.

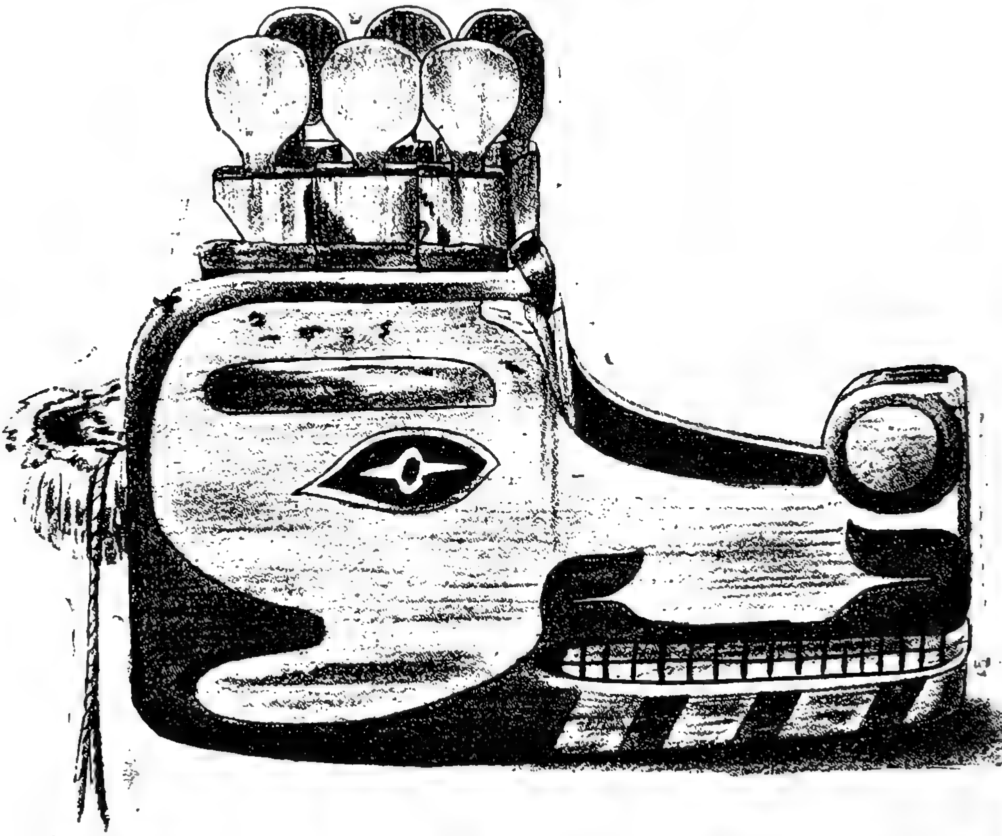
At night, when the whole tribe assembles in the taboo house, the societies still keep together. They are hostile to each other, and railleries between the various groups are continually going on. It seems that there are no separate societies for men and women, but a certain division must exist, as they seem to have separate feasts. When a man, during a Tlokoala, brings in any game, and he does not give half of it to the women, but retains the whole for the use of the men, the former will attack him and wrest the share due to them from the men. In the same way the women must share all they get or cook with the men.

Originally each dance belonged to one family, and was transmitted from generation to generation. Mother as well as father had the right to transfer their dance to their children. Thus dances which belonged to one tribe were transmitted to others. The dance was given to the novice at the time of his or her initiation, and no more than one dance could be given at a time. At present these restrictions are becoming extinct. Whoever is rich enough to distribute a sufficient amount of property may take any dance he likes. I was even told that the chief of the Tlokoala, at the beginning of the dancing season, distributes the various dances among the members of the order, and that he may redistribute them at the beginning of the following season.

It is a peculiarity of the dances of the Nootka that two masks of the same kind always dance together.

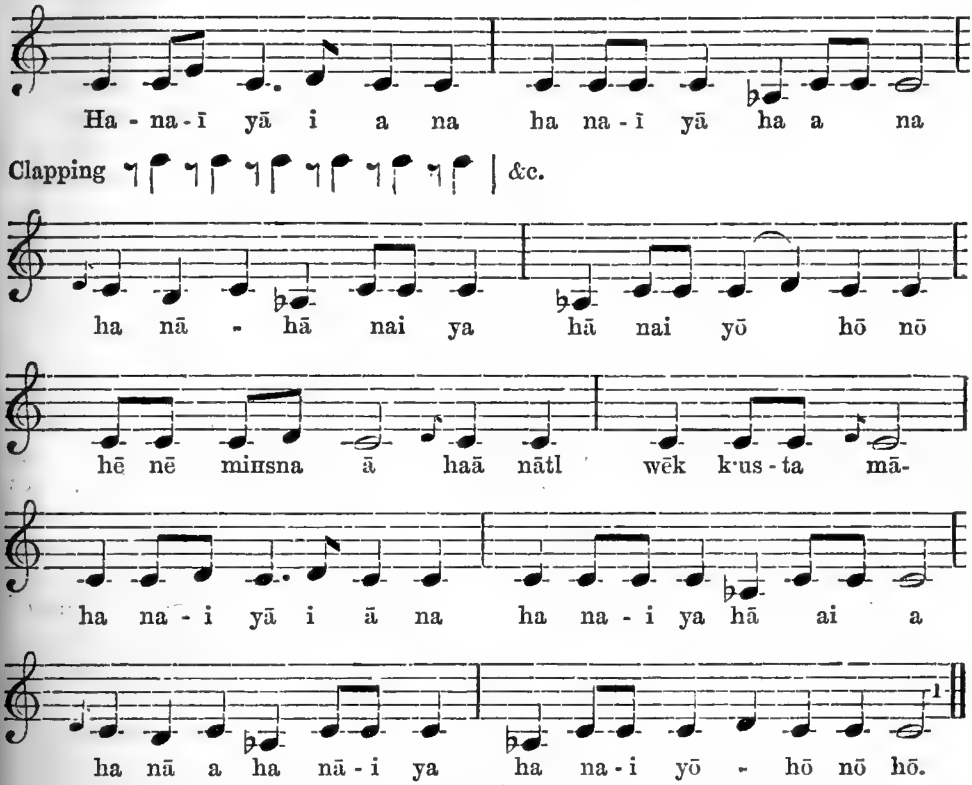
Among the dances belonging to the Tlokoala I mention the Aai′tlk·ē (=feathers on head). The Aai′tlk·ē is supposed to be a being living in the woods. He wears no mask, but a head-ornament of cedar-bark dyed red, the dyed cedar-bark being the emblem of the Tlokoala. This ornament consists of a ring from which four feathers wound with red cedar-bark rise, three over the forehead, one on the back. The face of the dancer is smeared with tallow and then strewn with down. The ornaments of each dancer—of the Aai′tlk·ē as well as of all others—must be

FIG. 17.—Head-mask of Hi′nemiн.

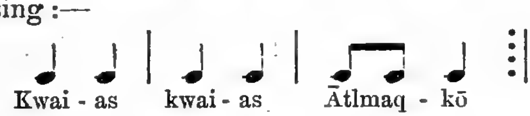


their personal property. They must not be loaned or borrowed. The following is the song of the Aai′tlk·ē:—

Another dance is that of the Hi′nemiн, a fabulous bird-like being. The dancers wear the head-mask, fig. 17. On the top of the mask there is a hole, in which a stick is fastened, which is greased and covered with down. When the dancer moves, the down becomes loose, and whoever among the spectators catches a feather receives a blanket from the chief of the Tlokoala. The following is the song of Hi′nemiH :—



The A′tlmaqkō is a dance in which two men wearing two human masks appear. The masks are called Ā′tlmaqkō. When they appear the spectators sing :—



I.e., Back out, back out, Ātlmaqkō !

Then they leave the house and run about in the village. The Ā′tlmaqkō is a being living in the woods. The first to see him was a Netcumu′asath, and ever since this sept dances the Ā′tlmaqkō dance.

The Sā′nEk (panther) dance corresponds to the Nō′ntlem of the Kwakiutl. The dancer wears a large head-mask, like that of the Hi′nemiH, and a bear-skin. He knocks everything to pieces, pours water into the fire, and tears dogs to pieces and devours them. Two canine teeth in the mouth of the mask are its most characteristic feature. A rope is tied around his waist, by which he is led by some attendants.

The *hī′tltak·*, self-torture, corresponds to the *hawī′natl* of the Kwakiutl. The dancers rub their bodies with the juice of certain herbs, and push small lances through the flesh of the arms, the back, and the flanks.

Other dances are the Pu′kmis dance (see p. 597), in which the dancer is covered all over with pipe clay; the Hu′tlmis dance, the Hu′tlmis

[1] The last note drawn down an eighth.

being another fabulous being living in the woods and always dancing; the Huē′mis dance, which is performed by women only, who wear red cedar-bark ornaments and down, and who dance with one hand extended upward, the other downward; the Ā′yēk· dance, in which the dancer knocks to pieces whatever he can lay his hands on; and dances representing a great variety of animals, particularly birds.

The tribes north of Barclay Sound have a dance in which the performer has to cut long parallel gashes into his breast and arms. The Hā′mats'a dance, which has been borrowed from the Kwakiutl, has spread as far south as Nutcā′lath, having been introduced there by intermarriage with the Kwakiutl. The killing of a slave, which has been described by Sproat (p. 157) and Knipping, may belong to this part of the Tlōkoala (see below, pp. 616, 617).

III. THE KWAKIUTL.

The Kwakiutl language is spoken in two main dialects, the Hēiltsuk·, from Gardner Channel to Rivers Inlet, and the Kwakiutl proper. I have formerly given the Lē′kwiltok· as a separate dialect, but this view has proved to be incorrect, it being almost identical with the Kwakiutl. As stated in my last report, the tribes speaking the Hēiltsuk· and Gyimanō-itq dialects are in the maternal stage, and are divided into gentes having animal totems; while the southern group are in the paternal stage, and are divided into gentes which have no animal-crest (see Fifth Report of Committee, p. 829). I collected in the summer of 1889 an almost complete list of tribes, septs, and gentes of the Kwakiutl, which is here given. The social position of the tribes and gentes will be discussed later on. The gentes of the Kwakiutl proper are given according to their rank.

A. Hēiltsuk· Dialect.

1. Qāisla′.

   Gentes: Beaver, Eagle, Wolf, Salmon, Raven, *Delphinus orca*.

2. Qanā′ks'iala, called by the Hēiltsuk· Gyimanō-itq.
3. Qē′qaes. Chinaman Hat.
4. Hē′iltsuk·. Bellabella.
   Septs: a. K·'ō′k·aitq
   b. Oē′tlitq
   c. Ō′ēalitq

   (3 and 4) *Gentes*: 1. Wīk'ōqtēnoq (eagle people); 2. K·'oē′tēnoq (raven people); 3. Ha′lq'aiнtēnoq (killer people).

5. Sō′mequlitq. Upper end of Awī′ky'ēnoq Lake.

   Gentes: 1. Sō′mequlitq.
   2. T'sē′ōkuimiq or Ts'ē′uitq.

6. Nō′qunts'itq. Lower end of Awī′ky'ēnoq Lake.
7. Awī′ky'ēnoq (=people of the back country?). Rivers Inlet. Called by former authors Wikēnō.

   Gentes: 1. K'oī′kyaqtēnoq. Crest: whale.
   2. Gyī′gyilk·am (=those first to receive). Crest: bear.
   3. Waō′kuitEm. Crest: raven.
   4. Wā′wikyem. „ : eagle.
   5. Kuē′tEla. „ : eagle.
   6. Nā′lekuitq. „ : whale.

B. Kwakiutl Dialect.

1. Tla′sk'ēnoq (=people of the ocean). Klaskino Inlet.

Gentes: 1. T'ē′t'anētlēnoq.
2. Ō′manitsēnoq (=people of Ō′manis, name of a place, alleged to be a Nootka word).

2. Gua′ts'ēnoq (=people of the north country). Northern side of entrance to Quatsino Sound.

Gentes: 1. Qâ′manâo.
2. Gua′ts'ēnoq.

3. Kyō′p'ēnoq. Entrance of Quatsino Sound.

Gentes: 1. Kyō′p'ēnoq.
2. K·'ō′tlēnoq.

4. K·osk·ē′moq. Koskimo.

Gentes: 1. Gyē′qsEm (=chiefs).
2. NEe′nsHa (=dirty teeth).
3. Gyē′qsEms'anatl (=higher than Gyē′qsEm ?).
4. Tsē′tsaa.
5. Wōquā′mis.
6. Gyēk·'ō′lEk·oa.
7. Kwākūk·Emā′l'ēnoq.

5. Nak·o′mgyilisila (=always staying in their country; descendants of K·'ā′nigyilak'). C. Scott.

Gentes: 1. Gyē′qsEm (=chiefs).
2. NEe′nsHa (=dirty teeth).

6. Tlatlasik·oa′la (=those on the ocean; descendants of NōmasE′nqilis). Nahwitti.

Gentes: 1. Gyī′gyilk·am (=those to whom is given first).
2. Lā′laōtla (=always crossing sea).
3. Gyē′qsEm (=chiefs).

7. Guasi′la (=north people). Smith Inlet.

Gentes: 1. Gyī′gyilk·am (=those to whom is given first).
2. Sī′sintlaē (=the Si′ntlaēs). Crest: sun.
3. K·'ō′mkyūtis (=the rich side).

8. Nā′k·oartok·. Seymour Inlet.

Gentes: 1. Gyē′qsEm (=chiefs).
2. Sī′sintlaē (=the Si′ntlaēs). Crest: sun.
3. Tsītsimē′lek·ala.
4. Wā′las (=the great ones).
5. TE′mtEmtlEls (=ground shakes when they step on it).
6. Kwā′kōkyūtl (=the Kwā′kiutl).

The Kwakiutl live at Fort Rupert, Turner Island, Call Creek. The tribe consists of the following three septs:—

9. Kuē'tEla.

Gentes: 1. Maa'mtagyila (=the Ma'tagyilas).
2. K'kwā'kum (=the real Kwā'kiutl).
3. Gyē'qsEm (=chiefs).
4. Laa'laqsEnt'aiō (=La'laqsEnt'aiōs).
5. Sī'sintlaē (=Sintlaēs).

10. K·'ō'moyuē (=the rich ones). War name: Kuē'qa (murderers).

Gentes: 1. K'kwā'kum (=the real Kwā'kiutl).
2. Hā'anatlēnoq (=the archers).
3. Yaai'HAk·Emaē (=the crabs).
4. Haai'lakyemaē (=the conjurers), or Lâ'qsē.
5. Gyī'gyilk·am (=those to whom is given first).

11. Wa'laskwakiutl (=the great Kwakiutl). Nickname: Lâ'kuilila (=the tramps).

Gentes: 1. Ts'E'ntsEnHk'aiō (=the Ts'E'nHk·aiōs).
2. Gyē'qsEm (=chiefs).
3. Wa'ulipoē (=those who are feared).
4. K·'ō'mkyūtis (=the rich side).

12. Ma'malēlek·ala (=Mā'lēlek·ala people). Village Island.

Gentes: 1. TE'mtEmtlEls (=ground shakes when they step on it).
2. Wē'ōmask·Ema(=high people).
3. Wā'las (=the great ones).
4. Mā'malēlēk·am (=the Mā'lēlek·as).

13. K·wē'k·sōt'ēnoq (=people of the other side). Gilford Island.

Gentes: 1. Nāqnā'qola (=standing higher than other tribes?).
2. Mē'mogyins (=with salmon traps).
3. Gyī'gyilk·am (=those to whom is given first).
4. Nē'nelpaē (=an upper end of river).

14. Tlau'itsis (=angry people). Cracroft and Turner Islands.

Gentes: 1. Sī'sintlaē (=the Si'ntlaēs).
2. Nunemasek·â'lis (=who were old from the beginning).
3. Tlē'tlk·ēt (=having great name).
4. Gyī'gyilk·am (=those to whom is given first).

15. NE'mk·ic. Nimkish River.

Gentes: 1. Tsētsētloa'lak·emaē (=the most famous ones).
2. TlātElā'min (=the supporters). Crest: eagle.
3. Gyī'gyilk·am (=those to whom is given first). Crest: thunder-bird.
4. Sī'sintlaē (=the Si'ntlaēs). Crest: sun.
5. Nē'nelky'ēnoq (=people of land at head of river).

[Mā'tilpē (=head of Māa'mtagyila) are no separate tribe. They belong to the Kwā'kiutl proper.

Gentes: 1. Maa'mtagyila.
2. Gyē'qsEm.
3. Haai'lakyEmāē.]

16. Tena'qtaq. Knight Inlet.

Gentes: 1. K·'a'mk·'amtElātl (=the K·'a'mtElātls).
2. Gyē'qsEm (=the chiefs).
3. K·oē'k·oaai'noq (=people of [river] K·oa'is).
4. Yaai'Hak·Emaē (=the crabs).
5. P'ē'patlē'noq (=the flyers).

17. Aoai'tlEla (=those inside of inlet). Knight Inlet.

Gentes: 1. Gyī'gyElk·am (=those to whom is given first).
2. Ts'ō'ts'ēna (=thunder-birds).
3. KH'ekHkH'ē'noq.

18. Tsā'watEēnoq (=people of the olachen country). Kingcombe Inlet.

Gentes: 1. Lē'lEwagyila (=the heaven-makers—mythical name of raven).
2. Gyī'gyEk·Emaē (=the highest chiefs).
3. Wī'ōk·Emaē (=whom none dares to look at).
4. Gyā'gygyilakya (=always wanting to kill people).
5. K·ā'k·awatilikya (=K·awatilikalas).

19. Guau'aēnoq. Drury Inlet.

Gentes: 1. Gyī'gyilk·am (=those to whom is given first).
2. Kwī'koaēnoq (=those at lower end of village).
3. Kwā'kōwēnoq.

20. Haquā'mis. Wakeman Sound.

Gentes: 1. Gyī'gyilk'am (=those to whom is given first).
2. Gyē'qsEm (=the chiefs).
3. Haai'alikyauaē (=the conjurers).
4. ?

The Lē'kwiltok·, who inhabit the country from Knight Inlet to Bute Inlet, consist of the following septs:

21. Wī'wēk·aē (=the Wē'k·aēs).

Gentes: 1. Gyī'gyilk·am (=those to whom is given first).
2. Gyē'qsEm (=the chiefs).
3. Gyē'qsEm (=the chiefs).
4. Wī'wēak·am (=the Wē'k·aē family).

22. Qā'qamātses (=old mats, so called because slaves of the Wī'wēk·aē). Recently they have taken the name of Wā'litsum (=the great ones).

Gentes: 1. Gyī'gyilk·am (=those to whom is given first).
2. Gyē'qsEm (=chiefs).

23. Kuē'qa (=murderers).

Gentes: 1. Wī'wēak·am (=the Wē'k·aē family).
2. K·'ō'mōyuē (=the rich ones).
3. Kuē'qa (=murderers).

24. Tlāa'luis. Since the great war with the southern tribes, which was waged in the middle of this century, they have joined the Kuē'qa, of whom they form a fourth gens.

25. K·'ō'm'ēnoq. Extinct.

Social Organisation.

The social organisation of the Kwakiutl is very difficult to understand. It appears that, in consequence of wars and other events, the number and arrangement of tribes and gentes have undergone considerable changes. Such events as that of the formation of a new tribe like the Mā'tilpi, or the entering of a small tribe into another as a new gens like the Tlaa'luis, seem to have occurred rather frequently. On the whole the definition given in my last report of a tribe as being a group of gentes the ancestors of whom originated at one place seems to be correct. The tribe is called *gyōuklūt* =village community, or *lē'lk·olatlē*, the gens *nEm'ē'mut* =fellows belonging to one group. The name of the gens is either the collective form of the name of the ancestor, or refers to the name of the place where it originated, or designates the rank of the gens. In the first case it appears clearly that the members of a gens were originally connected by ties of consanguinity. In the second case it would seem that historic events had led to the joining of a number of tribes, as mentioned above. For instance, in going over the list of the gentes of the NE'mk·ic, it would seem very likely that the Nē'nelky'ēnoq, the people of the land at the head of the river, who used to live in the interior of Vancouver Island, originally formed a separate tribe. In such cases in which gentes of various tribes bear the same name, the name being that of the ancestor, it seems likely that they formed originally one gens, which was split up in course of time. This seems most likely in cases in which the gentes refer their origin to a common mythical ancestor, as, for instance, that of the Sī'sintlaē. This opinion is also sustained by the tradition that the gentes were divided at the time of the flood, one part drifting here, the other there. The various gentes named Gyē'qsEm, Gyī'gyilk·am, &c., which names merely designate their rank, may have adopted these names independently, and are probably not branches of one older gens. Changes of names of gentes and tribes have occurred quite frequently. Thus the name K·'ō'mōyuē of one of the Kwakiutl tribes is a recent one. The name Wā'litsum has been adopted by the Qaqamā'tses only twenty or thirty years ago. The tribes Ma'malēlēk·ala and Wī'wēk·aē bear the names of their mythical ancestors, Mā'lēlēk·a and Wē'k·aē. They have gentes bearing the names of Mā'lēlēk·a's and Wē'k·aē's families. It seems probable that the other gentes joined the tribe later on. The impression conveyed by the arrangement of tribes and gentes is that their present arrangement is comparatively modern and has undergone great changes.[1]

According to the traditions of this people the K·osk·ē'moq, Gua'ts'ēnoq, Kyō'p'ēnoq, and Tla'sk'ēnoq drove tribes speaking the Nootka language from the region south of Quatsino Inlet. The K·osk·ē'moq are said to have exterminated a tribe of Kwakiutl lineage called Qō'ēas who lived on Quatsino Sound.[2] The Kwakiutl occupied the district from Hardy Bay to Turnour Island; the Nimkish the region about K·amatsin Lake and Nimkish River, and the Lēkwiltok· the country north-west of Salmon

[1] After the above was in type the interesting descriptions of the Apache gentes, by Capt. J. Bourke, and of the Navajo gentes, by Dr. W. Matthews, appeared (*Journ. Amer. Folk-Lore*, 1890, pp. 89, 111). Their conclusions regarding the gentes of these people closely agree with the views expressed above regarding the Kwakiutl.

[2] See also Dr. G. M. Dawson, *Trans. Roy. Soc. Canada*, 1887, ii. p. 70.

River. They did not conquer Valdes Island until the middle of last century.

The child does not belong by birth to the gens of his father or mother, but may be made a member of any gens to which his father, mother, grandparents, or great-grandparents belonged. Generally each child is made a member of another gens, the reason being prevention of poverty, as will be explained later on. The child becomes member of a gens by being given a name belonging to that gens. On this occasion property must be distributed among the members of the gens according to the rank of the name. By taking a name belonging to another gens, to which one of his ancestors belonged, a man may become at the same time a member of that gens. Thus chiefs are sometimes members of many gentes, and even of several tribes. One Kwakiutl chief, for instance, belongs to six gentes. The gentes differ in rank, and in festivals are placed accordingly, those highest in rank sitting in the rear of the house near the fire, the others arranged from that place towards the door, ranging according to rank. In each gens those highest in rank sit nearest the fire. The proper place of a gens is called *tlō'qoē*. The gens highest in rank receives its presents first. The latter are not given individually but in bundles, one for each gens. Those who belong to various gentes receive presents as members of each gens. Each man becomes debtor for double the amount of presents he has received, to be returned at convenience. Therefore those who belong to various gentes become as many times debtors as they are members of gentes. When a man dies his grandchild or child generally receives his name. Then the latter becomes responsible for all the debts of the deceased, and the outstanding debts of the deceased become due to him. If the child or grandchild does not take his name he does not need to pay the debts of the deceased, nor has he a claim upon outstanding debts. Children are generally given the names of deceased relatives, as then all debts become due to them, and they are thus provided for in case the father should die. For the same reason children of one family are made members of various gentes, so as to receive property as members of each gens. If a man has to give a great feast the members of his gens are bound to help him, and are assessed, according to their wealth, double the amount of the loaned property to be restored later on. The property given to a gens is distributed among its members according to rank and wealth.

The chiefs of various gentes of one tribe are, when still young, instigated by their elders to outdo each other in feats of bravery as well as in giving festivals. This spirit of rivalry is kept up throughout their lives, and they continually try to outdo each other as to who will distribute the greatest amount of property. Generally this strife is between the chiefs of two gentes; among the Nᴇmk·ic, for instance, between Tlā'g·ōtas, chief of the Ts'ētsētloā'lak·emaē, and Wā'qanit, chief of the Sī'sintlaē. The two opposite gentes always watch each other to see whether the opponent regards all the rules and restrictions by which the life of the Indians is regulated. If they detect their opponents in breaking a rule the latter have to make payments to them. In general it is not allowed that a woman give a feast; but by paying twenty blankets to the opposing gens permission may be obtained.

The method of acquiring certain privileges by marriage was described in the Fifth Report of the Committee (p. 849). It may be added here that when a man purchases a wife for his brother he also may take the privileges, particularly the dances, of the bride's father. The gentes are not exogamous, but marriages between cousins are forbidden.

Customs referring to Birth, Marriage, and Death.

The customs referring to birth, marriage, and death were described in the Fifth Report of the Committee. I have, however, to correct, to a certain extent, the statements referring to the dowry. Before and after marriage the woman begins to collect small copper plates (*tlā'tlaqsEm*), four of which are tied together and to the point of a short stick, and the *gyī'seqstâl*, each of which is valued at about one blanket. The *gyī'seqstâl* (=sea-otter teeth) or *kok·etayā'nō* (=lid of box) is a heavy board of cedar-wood about 2½ feet long by 1½ foot wide, resembling in shape somewhat the lids of Indian boxes, but being far heavier. Its front is painted and set with sea-otter teeth. All these boards are very old. When the woman has collected a sufficient quantity of these boards—sometimes as many as 200—she gives a feast. The *gyī'seqstâl* are placed in a long row on the beach, so that their fronts form one line. The men sit down on them, and beat time on the boards and sing. On this occasion the woman presents the boards and the coppers to her husband. I inquired once more as to the meaning of this peculiar institution. It would seem that it originally meant that the woman owned many boxes, each board representing one lid. But besides this the sea-otter teeth were considered a valuable possession, and it may be that this accounts for the fact that they are said to represent the woman's teeth. When a woman has not given *gyī'seqstâl* to her husband it will be said to her: *lōpHēpitō*, *i.e.*, you carry no teeth in your head, or *wī'pEt hā'mas laq tlā'k·oa k·'EHī't*, your teeth are not good to bite copper.

The Hēiltsuk· prepare corpses before burial by taking out the entrails and drying the body. A widow, in addition to the regulations recorded in my last report, must wear for four days after the death of her husband his clothing. From the fifth to the sixteenth day after the death she may lie down at night-time, but must sit up again before the crows cry in the morning. She must not comb her hair or cut it.

Parents of twins must for sixteen days after the children are born live in a corner of the house, paint their faces red, and strew their hair with eagle-down every fourth day.

Religion.

The Kwakiutl worship the sun, whom they call *ā'ta* and *gyī'k·amāē* (chief). It seems that his third name, *k·ants ō'ump* (our father), was not used before the advent of the whites, but this is not quite certain. He is also called 'our elder brother,' 'the one we pray to,' 'the praised one.' They pray to him. I recorded two formulas: In bad weather the steersman of the canoe will pray: *dō'koatla gyā'genuq! gyī'k·amāē! i.e.*, take care of us, chief! A frequent prayer is: *äi gyī'k·amāē! wā'watlē gyā'genuq! i.e.*, O chief, take pity upon us!

Besides the sun a host of spirits are worshipped, particularly those of the winter dances, as set forth in my last report (p. 850).

The soul is seated in the head, and may leave the body in sickness. It may be restored by the shaman. Two days before death the soul leaves the body. It becomes a Lâ'lēnoq, the sight of whom is deadly. The 'seer' sees the soul leaving the body, and therefore can predict the death of a man. The Lâ'lēnoq either live in Bēbēnak·aua (=the greatest depth) underground or roam through the woods. They are not permitted to enter a house and hover around the villages causing bad weather. It is said that the name of Bēbēnak·aua was not invented until after the advent of the whites, but the idea of the ghosts having their abode in the lower world is consistently carried through all tales and customs of the Kwakiutl as well as of the Nootka, and must therefore have existed before the whites arrived on the North Pacific coast. The soul of a deceased person returns again in the first child born after his death.

These beliefs are well described by the following tale, the events of which are believed to have happened comparatively recently. There were two chiefs among the Nak·oartok·, Ank·oa'lagyilis and Ts'ᴇq'ᴇ'tē. The former had given away many blankets and was Ts'ᴇq'ᴇ'tē's superior. He was one of twins, and used to say that *ā'ta*, the deity, took special care of him, and that he would go to him after death. He had been accumulating property for a new festival for four years. When the tribe went olachen fishing he hid his property under stones in the woods. His wife helped him. Ts'ᴇq'ᴇ'tē followed them unnoticed and killed them with his lance. He loaded the bodies with stones and threw them into the sea. Nobody knew what had happened to the chief and to his wife. Ank·oa'lagyilis had a son whom he had left to the care of one of his brothers. When the boy was grown up he married, and his wife had a son. It was Ank·oa'lagyilis who was thus born again. The boy when a few years old cried and wanted to have a small boat made, and when he had got it asked for a bow and arrows. His father scolded him for having so many wishes. Then the boy said, 'I was at one time your father, and have returned from heaven.' His father did not believe him, but then the boy said, 'You know that Ank·oa'lagyilis had gone to bury his property, and nobody knows where it is. I will show it to you.' He took his father right to the place where it lay hidden, and bade him distribute it. There were two canoe-loads of blankets. Now the people knew that Ank·oa'lagyilis had returned. He said, 'I was with *ā'ta*, but he has sent me back.' They asked him to tell about heaven, but he refused to do so. He became chief and refrained from taking revenge upon Ts'ᴇq'ᴇ'tē.

Shamanism and Witchcraft.

The shamans of the Kwakiutl are called *hē'ilikya*, *paqa'la*, or *nau'alak·*, the latter being the general name, while the first and second are only used for the shaman when curing disease. When curing a sick person he has a small dish of water standing next to him, and moistens the part of the body in which the pain is seated before beginning his incantations. He uses a rattle, dances, and finally sucks the disease out of the body (*kʜ'iqoa'*) which he shows to the bystanders, the disease being a piece of skin, a stick, a piece of bone or of quartz. He also uses whistles and blows the disease, which he holds in the hollow of his hands, into the air (*hē'ilikya* or *pō'qua*). He is also able to see the soul, and on account of this faculty is called *d'ō'qts'as*, the seer. In his dreams he sees leaving the body the souls of those who are to die within a short time. If a man feels weak and looks pale the seer is sent for. He feels the head and root of the nose of the patient, and finds that his soul has left his body. Then he orders a large fire to be made in the middle of the house, and when it is dark the people assemble and sit around the platform of the house, the sick one sitting near the fire. The shaman stands near him, and by means of incantations catches the soul, which he shows standing on the palm of his hand. It looks like a mannikin or like a small bird. Then he restores it to the patient by putting it on the crown of his head, whence it slides into his head. The soul is supposed to occupy the whole head.

The shaman is also able to hurt a man by throwing disease into his body (*mā'k·a*, see p. 622). He throws a stick, a piece of skin or quartz into the body of his enemy, who falls sick, and if the disease should strike his heart must die. The shamans of the Awīky'ēnoq occasionally perform a ceremony called *Mā'k·ap*, *i.e.*, throwing one another, in which two shamans try to strike each other with disease. The dance of the Mā'mak·a (see p. 622) represents the throwing of the disease by the shamans.

In order to bewitch an enemy two means may be applied. A portion of his clothing may be buried with a corpse (*lā'pEtantē*), or the ceremony called *ē'k·'a* may be performed. Particularly such parts of clothing are effective that are soiled and saturated with perspiration, for instance, kerchiefs, the lower parts of sleeves, &c. I learnt about two cases which occurred in 1887 and 1888 at Fort Rupert. In one case a girl fell sick, and as it was suspected that she was bewitched the box was opened in which a man who had recently died had been put up. Parts of her clothing were found in the mouth, nose, and ears of the body. The articles were taken away, the body washed with fresh water, and replaced. In the other case a grave was opened, and it was found that the tongue of the body had been pulled out, and its mouth stuffed with parts of clothing. This body was treated in the same way as the other one.

The second method of bewitching an enemy is practised by the *ē'k·'ēnoq* and is called *ē'k·'a*. This custom has been well described by Dr. G. M. Dawson:[1] 'An endeavour is first made to procure a lock of hair, some saliva, a piece of the sleeve and of the neck of the dress, or of the rim of the hat or headdress which has absorbed the perspiration of the person to be bewitched. These are placed with a small piece of the skin and flesh of a dead man, dried and roasted before the fire, and rubbed and pounded together. The mixture is then tied up in a piece of skin or cloth, which is covered over with spruce gum. The little package is next placed in a human bone, which is broken for the purpose, and afterwards carefully tied together and put within a human skull. This again is placed in a box which is tied up and gummed over, and then buried in the ground in such a way as to be barely covered. A fire is next built nearly, but not exactly, on the top of the box, so as to warm the whole. Then the evilly-disposed man, beating his head against a tree, names and denounces his enemy. This is done at night or in the early morning, and in secret, and is frequently repeated till the enemy dies. The actor must not smile or laugh, and must talk as little as possible till the spell has worked. If a man has reason to suppose that he is being practised on in this way he or his friends must endeavour to find the deposit and carefully unearth it. Rough handling of the box may

[1] *Trans. Roy. Soc. of Canada*, 1887, ii. p. 77.

prove immediately fatal. It is then cautiously unwrapped and the contents are thrown into the sea. If the evilly-disposed person was discovered he was in former years immediately killed. If after making up the little package of relics as above noted it is put into a frog, the mouth of which is tied up before it is released, a peculiar sickness is produced, which causes the abdomen of the person against whom the sorcery is directed to swell.' The reports which I have received agree in all the main points with the foregoing. Mr. George Hunt, of Fort Rupert, told me of an interesting experience. One day, when walking in the woods, he fell in with two men who had made a fire, and one of whom was holding his face and crying like a woman. The other moved a box towards the fire, keeping it covered with soil. When they saw that they were observed they ran away. Mr. Hunt took the box home, and was prevailed upon by a sick person called 'Captain Jim' to give it to him. The latter maintained to have felt a sudden pain and then a relief at the moment when the box was taken from the fire. He opened the box, and in it was found a human right femur, a right humerus, and a skull. The former had been split and tied up with human sinews. They were opened, and a piece of a shirt, a handkerchief, some saliva, a piece of the rim of a hat, and piece of a mat were found in the bones and in the skull. The nose, orbits, and foramen magnum of the skull were closed with leaves. The contents were thrown into the sea after being covered with feathers.

When a man knows that an *ē'k·'ēnoq* is bewitching him, he may call the *dē'gyintEēnoq*, who is able to undo the practices of the former. He goes through the same ceremonies, taking parts of the sick man's clothing, enclosing them in human bones, and making a fire over them. By performing these practices a second time the effect of the first performance is counteracted.

Various Beliefs.

The sight of a ghost is deadly. A few years ago a woman who was wailing for her mother suddenly fell into a swoon. The people first believed her to be dead, and carried the corpse into the woods. There they discovered that she continued to breathe. They watched her for two days, when she recovered. She told that she had seen two people enter the house. One of them had said, 'Don't cry; I am your mother's ghost. We are well off where we live.' She had replied: 'No, I mourn because you have left me alone.' Then she had fallen into a deep swoon.

When an eclipse of the sun or moon takes place the heavenly bodies are being swallowed. The eclipse is called *nEk·E'k'*=swallowed. In order to liberate the sun or the moon they make a great fire, and burn blankets, boxes, and food. They also make a noise to frighten away the enemy, and sing *hauk·uā!*=throw it up!

Earthquakes are produced by ghosts. To drive them away they make a noise and burn blankets, food, boxes, &c.

Wolves must not be killed, as else no game could be obtained.

Wolf's heart and fat are used as medicines for heart diseases.

Women are forbidden to touch a wolf, as else they would lose their husbands' affections.

Hair, nails, and old clothing are burnt as a protection against witchcraft. For the same reason they spit into water or fire.

When a salmon is killed its soul returns to the salmon country. The bones must be thrown into the sea, as they will be revived in that case. If they were burnt the soul of the salmon would be lost.

Twins, if of the same sex, were salmon before they were born. Among the Nak·o′mgyilisila the father dances for four days after the children have been born, with a large square rattle. The children by swinging this rattle can cure disease and procure favourable winds and weather.

A story that is worth being recorded is told by the NE′mk·ic regarding the supernatural powers of twins. An old woman named Wē′tsak·anītl, who died only a few years ago, had no teeth left. She was one of twins, and told the people that she would ask her father for new teeth. Then a few large black teeth grew in her mouth. Everyone came to see her. A few years later she said, 'I am getting too old. Don't cry when I die, I merely go to my father. If you cry, no more salmon will come here. Hang the box into which you will put my body on to a tree near the river after having painted it. When you pass by, ask me for salmon, and I shall send them.' She asked the chief, Na′ntsē (=Great Bear), 'Shall I become your child, and do you prefer a son or a daughter?' He asked her to become a boy, and seven months after her death his wife gave birth to a son, although she was quite old and had had no children since a long time.

Of another twin, a boy, it is told that after eating fresh salmon he became crazy, but regained his senses after having eaten half-dried olachen.

Secret Societies.

In my first report I have explained the principle underlying the secret societies of the Kwakiutl, and will merely repeat here that each class of this society has its ruling spirit, who initiates the novice, but that at the same time only such people are allowed to become members as have acquired the right of initiation by inheritance or marriage. Each class wears certain ornaments of cedar-bark which is dyed red, and called *tlā′k·ak·*. The highest in rank among the members of this society is the *hā′mats'a*, the eater, who devours the flesh of corpses and bites pieces of flesh out of the arms, breasts, back, or legs of the living. The season during which the festivities of the society are performed is called *Ts'ē′k·a* by the Kwakiutl, while the other tribes use generally the collective form *Ts'ētsā′ēk·a*, which means 'the secrets.' This season lasts from November to February. The rest of the year is called *Ba′qus*, the time during which the secret societies are forbidden to appear. The same name is applied to the uninitiated and to the festivities of summer. The *Ts'ētsā′ēk·a* does not last throughout the winter, but includes only a succession of dances, ceremonies, and feasts to which one man sends out invitations.

No more than four *Ts'ētsā′ēk·a* must be celebrated in one season. The man who gives the Ts'ētsā′ēk·a has to pay the expenses of the ceremonies, and particularly has to supply the immense quantities of food that are required. He is called *yē′wiHila*. He must have accumulated the following amount of property before he is allowed to become *yē′wiHila*: Two blankets for each man who is to take part in the festival, one spoon, one mat, ten pairs of copper bracelets, one pair of mountain-goat horn bracelets inlaid with haliotis shells, two fathoms of pearls, two tlā′tlaqsEm (see p. 610), and two gyī′sEqstâl (*ibid.*) for each man and for each woman, one dish and one box for each two persons.

The *Ts'ētsā′ēk·a* is celebrated when a novice or a member of the secret society returns from the woods after being initiated or after having had intercourse with the genius of his dance. Generally it is arranged in such a way that the man who intends to give the *Ts'ētsā'ēk·a* sends his son or some other relative into the woods. By his staying there with the spirits he will rise to a higher class of the society, and thus partake of the distinction arising from the celebration. But this is not necessarily the case. While the young man stays in the woods the *yē'wiʜila* sends two messengers around (*tlē'lala*) to give notice that he intends to give a *Ts'ētsā'ēk·a.* A few days before the beginning of the festivities he sends the same messengers to invite the people (*ä'etsēsta*), and finally at the night of the beginning of the festivals, when everything is ready, the messengers call the guests to come (*âlaʜ'it k·ā'tsīst*).

So far the customs are common to all tribes speaking the Kwakiutl dialect, but the details of the societies as well as their rank and the ceremonies of various dances differ somewhat among various tribes. Four groups may be distinguished, each having peculiar customs. The first comprise the Kwakiutl, Nemk·ic, Ma'malēlēk·ala (Matilpi), Tlau'itsis, Tena'qtaq, and Lē'kwiltok·; the second the Tsā'watᴇēnoq, Guau'aēnoq, and Haquā'-mis; the third, the Tlatlalisk·oa'la, Nak·o'mgyilisila, Na'k·oartok·, and Guasi'la; the fourth, the K·oskē'moq, Kyō'p'ēnoq, Tla'sk'ēnoq, and Gua'ts'ēnoq. I shall first describe the customs of the first group.

Some time before the beginning of the festivities the *yē'wiʜila* must give a large quantity of cedar-bark to the 'master of the cedar-bark' (*tlā'tlak·ak·sila*), who has to make all the ornaments for the various members of the Ts'ētsā'ēk·a. Four days after he has received the bark he invites the whole tribe and distributes the ornaments. This festival is called *k·ap'ē'k'*. He also gives to all those present three kinds of tallow for smearing the face, mountain-goat, deer, and *k·ā'tsek* (?) tallow. This office is acquired by being inherited from the father, not by marriage. There are three more offices of a similar kind which are inherited in the same way, that of the singing-master, who teaches songs and rhythms, the baton-master (*t'ā'miatsē*), who has to procure the batons for beating time; and the drum-master (*mā'mᴇnatsīla*), who has to look after the drum.

As soon as the Ts'ētsā'ēk·a begins, the gentes and the social rank of ordinary times are suspended, and a new arrangement takes place. The people drop their ordinary names and assume their Ts'ētsā'ēk·a names. The tribe is divided into two groups, the *mē'emkoat* (seals) and the *k·uē'k·utsē*, the former being higher in rank. All those who are initiated may become members of the *mē'emkoat*, but they are at liberty to join the *k·uē'k·utsē* for one *Ts'ētsā'ēk·a.* They have to pay a number of blankets to the *mē'emkoat* for obtaining the right to stay away from the group to which they properly belong. Only the highest grade of the members of the Ts'ētsā'ēk·a, the *hā'mats'a*, must join the *mē'emkoat.* They must dress in black, and, it is said, are called 'seals' for this reason. The house of the *yē'wiʜila* is their house, and is tabooed as long as the ceremonies last. It is called *tlamē'latsē*, and no uninitiated (*Ba'qus*) is allowed to enter. They have to stay in this house throughout the duration of the *Ts'ētsā'ēk·a.* Sometimes a large ring of cedar-bark dyed red, the emblem of the society, is fastened to the door of the house to indicate that it is tabooed. The *hā'mats'a* is the chief of the *mē'emkoat*, and, therefore, during the festival, of the whole tribe. If a member of the *mē'emkoat* wishes to leave the house he must obtain his permission first. When the *hā'mats'a* wishes to obtain food he may send anyone hunting or fishing, and his orders must be obeyed. Only during dances and feasts the uninitiated are admitted to the taboo house. If anyone intends to invite the *mē'emkoat* to a feast the *hā'matsa's* wife may enter the house and deliver the message after having publicly announced that she will go there. The *mē'emkoat* are not permitted to touch their wives, but nowadays this custom is mostly restricted to the *hā'mats'a.*

The *k·uē'k·utsē* are subdivided into seven societies:

1. *Māa'mq'ēnoq* (killer whales), the young men.
2. *D'ō'd'ōp'E* (rock-cods), men about thirty to forty years of age.
3. *Tlē'tlaqan* (sea-lions), men forty to fifty years old.
4. *K·oē'k·oim* (whales), old men and old chiefs.
5. *Kēkyaqalā'k·a* (crows), girls.
6. *K·ā'k·ak·ao* (chickens), formerly called *wā'qwaqoli* (a small species of birds), young women.
7. *Mō'smōs* (cows), old women.[1] (This name was recently adopted, but I did not learn the old name.)

During the *Ts'ētsā'ēk·a* all these societies wear ornaments of the animals which they represent. They are opponents of the *mē'emkoat.* The *mē'emkoat* and each of the groups of the *k·uē'k·utsē* give feasts to each other 'in order to keep their opponents in good humour.' Nevertheless the *k·uē'k·utsē* always attempt to excite the *mē'emkoat,* as will be described presently, and the latter will attack the *k·uē'k·utsē.* The natives consider these festivals not purely from a religious point of view, although the latter is their principal character, but it is at the same time the social event of the year, in which merry-making and sports of all sorts are enjoyed. Even the attacks of the *mē'emkoat,* which will be described hereafter, are considered as part of the 'fun.'

The *mē'emkoat* are subdivided into a great number of classes which have different rank. I give here the list of the divisions of the *mē'emkoat* arranged according to rank:

1. Hā'mats'a.
2. Nō'ntsistatl.
3. K·'oē'k·oastatl.
4. Nū'tlmatl.
5. Nā'nē.
6. Tō'q'uit.
7. Hā'ilikyilatl.
8. Mē'itla.
9. Nō'ntlEm.
10. Kyimk·'alatla.
11. Tlōkoa'la.
12. IakHiatā'latl.
13. K·'ō'malatl.
14. Hawī'nalatl.

Then follow a number of dances, which are all of equal rank: Hā'masElatl, Hā'ok·hāok·, Ku'nqulatl, K·ō'lus, and many others. The last is the Lōlō'tlalatl, which is as high in rank as the Hā'mats'a, but is opposed to him, and therefore stands at the other end of the dancers.

[1] This peculiar custom of suspending the gentes on certain occasions, and introducing a class system instead, seems worthy of attention. Although this fact is far from being a proof of the former existence of such a system among the Kwakiutl, still its correspondence to the Australian class system is certainly suggestive, and may point to a development of the social institutions of these tribes. The idea of the possibility of suspending all gentes points out that the latter are either of comparatively recent origin or that they are degenerating. The former alternative appears more probable, as in religious festivities, such as the *Ts'ētsā'ēk·a.* Generally ancient institutions are preserved. It is hardly necessary to mention that similar class systems are found east of the Rocky Mountains.

1. The *Hā'mats'a* and the *Nō'ntsistatl* are initiated by Baqbakuālanusī'uaē,[1] Baqbakuā'latlē, Hā'maa, or Hā'ok·hāok·, the first being, however, by far the most important. During the dancing season the *hā'mats'a* may devour corpses and bite people. It seems that in former times they also killed and devoured slaves. His ornaments are a very large head-ring, three neck-rings and bunches tied into his hair, around his wrists and ankles, all these ornaments being made of cedar-bark dyed red. His face is painted black. He has six large whistles, each whistle being a combination of several whistles with one common mouthpiece. They are called *mᴇtsē's*, which is said to mean 'making him gay.' He dances in a squatting position, his arms being extended horizontally, first to one side, then to the other. His hands tremble continually. His eyes are staring, his lips protruding voluptuously. Others in dancing keep their hands pressed against the belly, to keep back the spirits which are supposed to dwell in the belly, and whose voices are heard, their voices being the sounds of the whistles. When dancing the *hā'mats'a* cries *hāp hāp!* On the morning when the *hā'mats'a* returns from the woods at the beginning of the *Ts'ētsā'ēk·a* he uses hemlock wreaths instead of cedar-bark rings. On the same evening he dances with his cedar-bark ornaments. Sometimes the *hā'mats'a* has two or four rattles. He does not swing them himself, but has four companions, called *hāili'kya* or *sâ'latlila*, who stand around him rattling. The highest *hā'mats'a* use the masks of the *hā'ok·haok·*, or of the *g·alō'kwīois*. Women cannot attain the rank of the highest *hā'mats'a*, although they can become members of the fraternity. They use the *ha'msīuē* (*i.e.*, *hā'matsa's* mask for the forehead), but do not dance themselves, a man acting in their stead. One cannot become *hā'mats'a* unless one has been a member of one of the lower ranks of the *Ts'ētsā'ēk·a* for eight years. When the *hā'mats'a* returns from the woods the *kyi'mk·'alatla* (No. 10), who is his servant, must attend him. The latter carries a large head-ring, a small whistle, and a large rattle. He carries a corpse on his arms, and thus entices the *hā'mats'a* to follow him into the dancing-house. From the moment when he is found in the woods the *sâ'latlila* surround him. The *kyi'mk·'alatla* leads him into the rear of the house, leaving the large fire which is burning in the centre of the house to his left. Then he deposits the corpse, and tastes its flesh four times before giving it to the *hā'mats'a*. When the latter begins to devour the flesh, which he must bolt, not chew, the *kyi'mk·'alatla* brings him water, which the *hā'mats'a* drinks in between. The *kyi'mk·'alatla* cuts the flesh in narrow strips. The bodies which are used in this ceremony are prepared by being soaked in salt water. The flesh is removed from under the skin with sharp sticks, so that only skin, sinews, and bones remain. When the other *hā'mats'a* see the corpse they make a rush at it, and fight for the flesh. The *kyi'mk·'alatla* breaks the skull and the bones, and gives them the brains and the marrow. It was stated above that the *k·uē'k·utsē* always try to excite the *mē'emkoat*, and particularly the *hā'mats'a*. This is done by transgressions of any of the numerous rules relating to the intercourse with the *hā'mats'a*. Nobody is allowed to eat until he has begun. Or: he is offered a feast. A kettle is filled with food, and as soon as it begins to boil they will upset the kettle. When a *Lōlō'tlalatl* (ghost dance) song is sung the *hā'mats'a* will become excited as soon as the word

[1] See *Journ. Amer. Folk-Lore*, i. p. 53, ff.

Lâ'lēnoq (ghost) occurs, the *Lōlō'tlalatl* being his opponent. As soon as the *hā'mats'a* gets excited the *nū'tlmatl* will close the door and prevent the escape of those present. Then the *hā'mats'a* rushes around and bites the people. At the same time, when the *nū'tlmatl* rises, the *kyi'mk·'alatla* must rise and attend his master, the *hā'mats'a* following all his movements. If the latter is unable to get hold of anyone else he bites the *kyi'mk·'alatla.* When the *hā'mats'a* returns from the woods a post called *ha'mspiq* (=eat-post) is erected in the dancing-house, and remains there for four days. It is a high pole, with a short cross-piece on top. It is wound with red cedar-bark, which spreads toward the cross-piece in the shape of a fish-tail. After the fourth night the pole and the cedar-bark are burnt. During the *Ts'ētsā'ēk·a* season the *hā'mats'a* must speak in whispers only. When he has eaten a corpse he has to observe certain very strict regulations for four months after the end of the dancing season before he is allowed to have unobstructed intercourse with the rest of the tribe. He is not allowed to go out at the door, but a separate opening is cut for his use. When he rises he must turn round four times, turning to the left. Then he must put forward his foot four times before actually making a step. In the same way he has to make four steps before going out of the door. When he re-enters the house he has to go through the same ceremonies before passing the door, and must turn round four times before sitting down. He must use a kettle, dish, spoon, and cup of his own, which are thrown away at the end of the four months. Before taking water out of the bucket or river he must dip his cup four times into the water before actually taking any. He must not take more than four mouthfuls at one time. When he eats boiled salmon he must not blow on it in order to cool it. During this period he must carry a wing-bone of an eagle, and drink through it, as his lips must not touch the brim of his cup. He also wears a copper nail to scratch his head with, as his nails must not touch his skin, else, it is believed, they would come off. At the end of the *Ts'ētsā'ēk·a* many people surround the *hā'mats'a* and lead him into every house of the village and then back to the dancing-house. This is called *wā'lēk·a.* When the dancing season is over, the *hā'mats'a* feigns to have forgotten all the ordinary ways of men and has to learn everything anew. He acts as though he were very hungry. The bones of the corpse he has eaten are kept for four months. They are kept alternately four days in his bedroom and four days under rocks in the sea. Finally they are thrown into the sea. After the *Ts'ētsā'ēk·a* is over he has to pay everyone whom he has bitten. It is said that the Kwakiutl obtained the *hā'mats'a* ceremonies from the Awī'ky'ēnoq, Tsā'watᴇēnoq, and Hēiltsuk·.

2. The Nō'ntsistātl is also initiated by Baqbakualanusī'uaē. He is painted black, covered with ashes, and carries firebrands, which he brandishes in dancing. He has two whistles, is allowed to bite people, and eats out of one dish with the *hā'mats'a.*

3. K·'oē'k·oastatl (from *k·'oē'k·oasa*, to beg), the beggar dancer, carries two whistles. He is so called because anything he asks for must be given him.

4. Nū'tlmatl (=the fool dance). The Nūtlmatl carries a lance, sticks, or stones. When he is excited by the *k·uē'k·ntsē* he knocks to pieces what he can lay his hands upon, and strikes the people. In order to excite him they sing a song taken from a legend referring to the mink and the wolves. Mink, Tlē'selagyilak‘ (= made the sun), had killed two sons of

the chief of the Atlâ'lēnoq (= wolves), who were preparing themselves in the woods for the *Ts'ētsā'ēk·a*. The Atlâ'lēnoq learnt that he had committed the murder, and invited him to a feast, during which they intended to kill him. He came and sang: *K·ap'amā'luq* *Kʜēʜ* *aqō nᴇk·amā'eaqs Atlâ'lēnoq*, *i.e.*, Kʜēʜ (=mink), took the middle of face (= nose) of Atlâ'lēnoq for his cap. This song is used 'to make the Nūtlmatl wild.' If anyone makes a mistake in dancing he is killed by the Nūtlmatl, who is assisted by Nā'nē, the grizzly bear. (See also No. 14.)

5. Nā'nē, the grizzly bear, also knocks down people when he is excited. He hates the red colour. (See also Nos. 4 and 14.)

6. Tō'q'uit is danced by women, the arms of the dancer being raised high upward, the palms of her hands being turned forward. The upper part of the dancer's body is naked; hemlock branches are tied around her waist. She has four attendants, who always surround her. The dance is said to have been originally a war-dance. The warriors, before going on an expedition, went into the woods in order to meet the double-headed snake, the Sī'siutl, which gives them great strength and power. After returning from the woods they engage a woman to dance the Tō'q'uit. Very elaborate arrangements are made for this dance. A double-headed snake, about 20 feet long, made of wood, blankets, and skins, is hidden in a long ditch, which is partly covered with boards. Strings are attached to it, which pass over the beams of the house, and are worked by men who hide in the bedrooms. As soon as the dancer appears, the people begin to sing and to beat time. In dancing the woman acts as though she were trying to catch something, and when she is supposed to have got it she throws back her hands and the Sī'siutl rises from out of the ground, moving its heads. If it does not move properly the Hā'mats'a, Nō'ntsistātl, Nū'tlmatl, and the bear jump up and bite and strike the people, driving them out of the house. Finally the snake disappears in the ditch. A messenger next calls upon one of the attendants to kill the dancer. Apparently a wedge is driven through her head. It consists of two parts, each being fastened to one side. She continues to dance, the wedge sticking out of both temples, and blood flowing down freely. Then her head is struck with a paddle, which is cut out so as to fit in the head, and she continues to dance, her head being apparently split by the paddle. Sometimes she is burnt. For this purpose a box having a double bottom is prepared. She lies down, and the box is turned over so that her body may be conveniently pushed into it. At the place where she lies down a pit is dug, in which she hides. The box is turned up again, closed, and thrown into the fire. Before the beginning of the ceremony a corpse has been put into the lower part of the box. From the pit in which the dancer hides, a tube of kelp has been laid underground, leading to the centre of the fire. It acts as a speaking tube. The woman sings through it, and her voice apparently comes out of the fire. Afterwards the bones are found in the fire. They are collected, laid on a new mat, and for four days the people sing over the bones, while the woman remains hidden in a bedroom. At last the bones are heard to sing (which is done by placing the mat over the mouth of the speaking tube), and the next morning the woman is seen to be once more alive. After the woman has been apparently killed the *d'ᴇ'ntsik·* is seen behind the spectators. It consists of a series of flat carved boards, which are connected on their narrow sides by plugs, which are passed through rings of cedar

FIG. 18.—D'E'ntsik.

ropes. It has two or three points on top, and is ornamented with mica (fig. 18). It is intended to represent the Sī'siutl. It is set in undulating motions. Generally three of these figures appear. In the Tō'q'uit the Nō'ntlᴇmgyila (=making foolish) is also used. It is a small, flat, human figure with movable head and arms. Two lines of mica run from the eyes to the corners of the mouth. Its head is set with bunches of human hair. In a number of these figures the head can be taken off, being inserted into the body by means of a plug. Then two carved birds are used, which fly down from the roof, flapping their leather wings. They grasp the head and carry it away, to return it after a while. The figure is also worked from underground.

7. Hā'ilikyilatl is the conjurer's dance.

9. Nō'ntlᴇm dances the hands alternately, one turned up to the shoulder, the other downward and backward as far as possible.

10. Regarding the Kyi'mk·'alatla see p. 617.

11. The Tlōkoa'la is the wolf's dance. It corresponds almost exactly to the Tlōkoala of the Nootka (see p. 599). They wear the *Hīsī'uaē*, a small carved wolf's head, on the forehead. They crawl on the knuckles of the fingers, the thumbs turned backward, and on the toes around the fire.

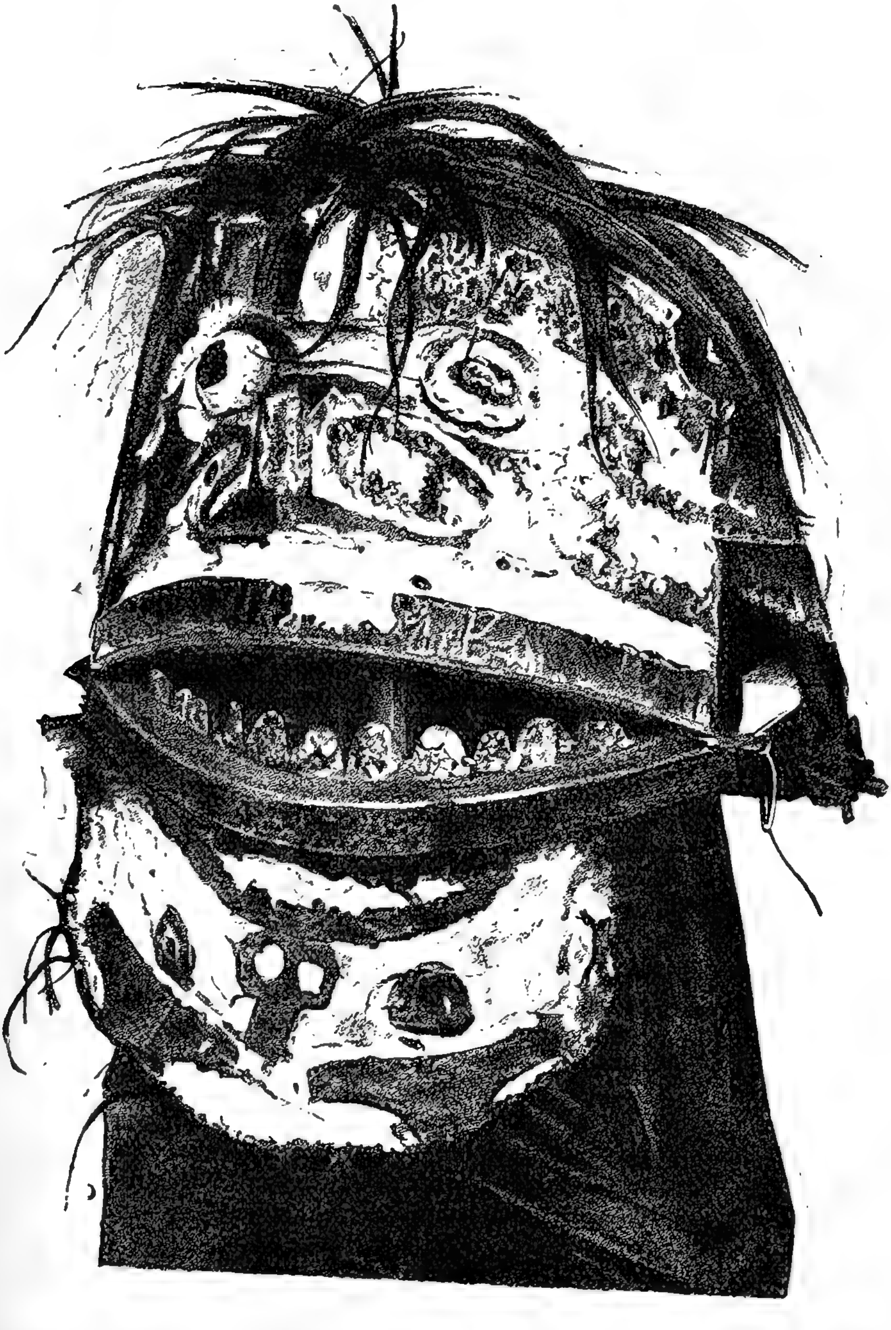
12. Iakʜiatā'latl. Dance of the sea-monster or lake-monster Ia'kʜim with the mask (fig. 19).

13. The K·'ō'malatl is initiated by the bird Mātᴇ'm, who is said to live on a high mountain inland, and conveys supernatural powers, particularly the faculty of flying, through pieces of quartz, which he gives the novice. The dancer's body is covered with blood, and he has five pieces of quartz in his hair, arranged on the medial line.

14. Hawī'nalatl. The Hawī'nalatl is initiated by the Winā'lagyilis, a genius of warriors. The Hawī'nalatl has his shoulders and thighs perforated, and ropes pulled through the wounds. Small and thin slabs of wood are sewed to his hands. A heavy post is leaned against the front of the dancing-house, and a block is fastened to its top. A rope is passed over the block and fastened to the ropes which have been pulled through the Hawī'nalatl's flesh. He is raised on the pole, hanging from these ropes. He carries a Sī'siutl knife, with which he himself cuts his wounds, and wears a Sī'siutl belt. The Hā'mats'a, Nūtlmatl, and bear stand around him. If the ropes should give way the latter two kill him, while the Hā'mats'a devours him.

In the Lōlō'tlalatl dance the dancer appears to be taken by the ghosts to the lower world. For this purpose a long, deep ditch is dug out behind the fire. The dancer, who wears a long veil of cedar-bark over his face, has a rope tied round his waist, which is held

FIG. 19.—Ia'kHim Head-mask.



by his attendants. Speaking tubes of kelp are laid so as to terminate in the fire. Through these many voices are heard, and the ghosts take the dancer into the lower world, *i.e.*, he disappears in his ditch, drawing the rope after him, while the others feign to try to hold him. After a while the voices are heard again, and a black head is seen rising from the earth, which brings him back.

The members of the *Ts'ētsā'ēk·a* among the TsāwatEēnoq, Guau'aēnoq, and Haquā'mis are the following, arranged according to rank:—

1. Mā'mak·'a.
2. Hā'mats'a.
3. Hai'ak·'antElatl (= speaker dance).
4. Hauē'qak·ulatl induces chiefs to break coppers, to destroy property, &c.
5. Walas'aqā'atl.
6. Hauā'iadalatl.

The Mā'mak·'a (= the thrower) dances with his palms laid against one another, making motions like a swimmer. Suddenly he is supposed to have found his magical stick, which he throws upon the bystanders. One of them falls down, and blood flows from his head. He has been wounded by the Mā'mak·'a, who then extracts his stick. The latter consists of a hollow piece of wood, in which another piece slides up and down. It is covered with skin, so that it appears as though the stick decreases and increases in size.

The Walas'aqā'atl (=great dance from above) belonged formerly also to the first group of tribes. It was, however, taken from them in a war. It is somewhat related to the Tlōkoa'la. In the dance a great wolf appears from above. It is danced by men and women.

The Hauā'iadalatl swings a great knife. He pretends to cut his throat at each beating of the drum.

The K·o'sk·ēmoq, Ky'ōp'ēnoq, Tlask'ēnoq, and Gua'ts'ēnoq have the following dances, arranged according to rank, so far as I am acquainted with their dances:—

1. Tō'q'uit.
2. Mā'mak·'a.
3. Hā'mats'a.

It is stated that they acquired the Hā'mats'a from the last group, which comprises the Tlatlasik·oala, Nak·o'mgyilisila, Nā'k·oartok·, and Guasi'la. They have two dancing seasons in winter, the first called *Nō'ntlEm*, and lasting from November to about the winter solstice, and the *Ts'ētsā'ēk·a* during the following two months. During the Nō'ntlEm the gentes remain in force. Instead of cedar-bark, which has been dyed red, undyed cedar-bark; instead of eagle feathers and down, feathers and down of the cormorant are used. Songs belonging to the *Ba'qus* (see p. 614), *Nō'ntlEm*, and *Ts'ētsā'ēk·a* are sung. There is no difference in rank of the various members of this society. Here belong all the animals and birds which among the Kwakiutl belong to the *Ts'ētsā'ēk·a* and also the Nū'tlmatl and Hāwī'nalatl. The Nū'tlmatl has not the same duties as among the Kwakiutl. When the Hāwī'nalatl's ropes tear out of the flesh he is not killed, but the conjurers heal him.

The members of the *Ts'ētsā'ēk·a* are the following, according to their rank:—

1. Mā'mak·'a.
2. Hā'mats'a.
3. Ō'lala (=Tō'q'uit of the Kwakiutl). It contains the Ts'ē'kois and Sī'lis.

4. Lōlō'tlalatl.
5. Hai'alikyalatl.
6. Yiā'iatalatl.
7. Pā'qalalatl, a female conjurer, who has to sooth the Hā'mats'a and keep him from using his whistles.
8. Wā'tanum. Those who join for the first time the *Ts'ētsā'ēk·a*, *i.e.*, novices of the lowest grade.

Among this group the Hā'mats'a, on returning from the woods, dances four nights with wreaths of hemlock branches; the following four nights (fifth to eighth) with no ornaments whatever; then four nights (ninth to twelfth) with ornaments of red cedar-bark. He wears eight bundles over his forehead which are called *ky'a'sīwē*, and four on each side. The following night (thirteenth), after he has finished dancing, one of the *ky'a'sīwē* is taken off, which is publicly announced on the following morning. The fourteenth night two more of these bundles are taken away; the next, two more; and finally, the sixteenth, one more, which is also publicly announced each morning. The seventeenth night a black line is drawn over his face from the left side of his forehead to the right side of his chin, and then he rises to bite people. Later on he is excited by mistakes made in songs, and by Lōlō'tlalatl songs.

The gentes are suspended during the *Ts'ētsā'ēk·a*, and societies take their place. The members of the *Ts'ētsā'ēk·a* are called K·'ā'k·anā's ('stickshoes' ?). If a dancer makes a mistake he is tied up in a blanket, thrown into the fire, and roasted alive.[1]

The following customs belong to the Kwakiutl group, but are probably more or less in common to all those tribes.

In order to become a member of any one of these societies the novice must be initiated by the spirit of the grade he intends to occupy. But when first entering the society the novice must take the lowest degree, from which he may gradually rise. A number of these grades are the property of certain gentes, so that anyone who is a member of the gens may acquire it, provided he finds someone who is willing to give the *Ts'ētsā'ēk·a* for him. For instance, the Hā'ili'kyilatl belongs to the gens Haai'lakyemaē of the K·'ō'mōyuē. As a rule, however, the right to become a member of the respective grade of the society is acquired by marriage, after the consent of the council has been obtained. After the marriage has been consummated the woman's father must give up his dance to his son-in-law, as described in my last report (p. 838). If a man purchases a wife on behalf of his brother he may take the woman's father's dance.

The father of the novice gives a feast, at which the young man dances, and then retires to the woods, where he must prepare himself by fasting and bathing for the encounter with the spirit. The spirits appear only to clean men; others are not likely to see them, and if they did the spirits would kill them. Sometimes the novice disappears suddenly during the feast, and is supposed to have flown away. After he has been initiated by the spirit of the grade he wishes to acquire he returns to the village, and his whistle or his voice is heard in the woods. Then the *yē'wiʜila*, who is to give the *Ts'ētsā'ēk·a*, calls the whole tribe to the first dance, which is called *kikyi'lnala*. The *yē'wiʜila* has to give

[1] I have no trustworthy information regarding the rank of dances of the Hē'iltsuk·. They call the Hā'mats'a, Tanī's.

the more presents during the *Ts'ētsā'ēk·a,* the higher the grade is that the novice has acquired.

On this day each society, after having received their cedar-bark rings from the *tlā'tlak·ak·sila*, goes into the woods and holds a meeting, in which their chief instructs them regarding their dances. This is called *NūtlEmū'tl'Els* (=beginning of foolishness). All those who make mistakes later on are killed by the Nūtlmatl.

In the evening the *yē'wiHila* sends out two male messengers to invite all people to his house, which henceforth is the taboo-house of the *mē'emkoat*. The messengers say: *lamEnts wutlā'qotlē pēpaqa'la* (let us all try to bring him back by our sacred dances). The people assemble and sit down in groups, each society by itself. The *mē'emkoat* have the places of honour, and among them the *hā'mats'a* has the first place, sitting in the rear of the house in the middle. The other *mē'emkoat* are arranged at his sides according to rank around the house, the lower in rank the farther from the *hā'mats'a* and the nearer the door. The *Lōlō'tlalatl*, who is as high in rank as the *hā'mats'a*, sits close to the door opposite the *hā'mats'a*. The societies dance one after the other, according to rank, the Māa'mq'ēnoq beginning. The *yē'wiHila* stands in the middle of the house, two messengers attending him. These he despatches to members of the various societies, and orders them to dance. The interval until the dancers are dressed up and make their appearance is filled with railleries between the messengers. For instance, if a woman is to dance, the one will say: 'She will not come; when I brought her the message she was fighting with her husband.' The other will answer: 'Oh, you liar! She is dressing herself up, and you will see how nice she looks!' As soon as the two watchmen who stand at the door see her coming they begin swinging their rattles, and then the people begin to sing and to beat time with their batons, which were distributed by the *t'ā'miatsē* (see p. 615). When the festival begins, the 'drum-master' carries his drum into the house on his shoulder, going four times around the fire, which is on his left, before he takes his place in one of the rear corners of the house. While making his circuit he sings a certain song. The dancer enters the house, and, turning to the right, goes around the fire until he arrives in the rear part of the house. Then the people stop singing and beating time until his dance begins. The dancer first faces the *hā'mats'a*, who sits in the rear of the house. Then he turns to the left, to the fire, and finally faces the *hā'mats'a* again. He leaves the house, having the fire on his left side. Thus all the societies dance. The last are the *mē'emkoat*, the members of whom dance according to rank, the lowest first, the *hā'mats'a* last. After his dance whistles are suddenly heard outside the house, and the novice appears on the roof of the house, where he dances, eventually thrusting his arms down into the house; but finally he disappears again.

On the next morning the whole tribe goes into the forest to catch the novice. They take a long rope made of cedar-bark, and having arrived at an open place lay it on the ground in form of a square. They then sit down inside the square, all along the rope, and sing four new songs composed for the purpose. The two first are in a quick binary measure, the third in a five-part measure, and the last in a slow movement.

1, 2.

One man dances in the centre of the square. Meanwhile the wife of the *yē'wiнila* invites the women and the old men to a feast which is celebrated in the house. All the men are painted black, the women red. They wear headrings of red cedar-bark, and their hair is strewn with eagle down. The men who are in the forest wear headrings and necklets of hemlock branches. While they are singing and dancing the novice appears. He looks pale and haggard from continued fasting; his hair falls out readily. His attendants surround him at once, and he is taken back to the village, where he performs his dances and ceremonies.[1]

In the winter of 1886–87 I collected a number of *Ts'ētsa'ēk·a* songs in Newette Nahwitti without being able to obtain a translation. In the summer of 1889 I read my notes to a number of natives of Alert Bay, and obtained the translation and explanations. All the songs consist of four parts, but I have not obtained the complete songs in all instances. I give a series of these songs here :—

I. *Hā'mats'a.*

1. Hāok·haok·qō'laē sta'mkнti ūwēsta'kqtis nā'la.
Hāok·haok·'s voice is all around the world.

Hōqōnā'kolastlas ts'ē'tsēqk·enqēlis lō'wa!
Assemble at your places. all the lower dances around the edge of the world

2. K·uik·uaqō'laē stamkнti ūwēsta'kqtis nā'la.
The raven's voice is all around the world.

Kyimk·onā'kolastlas bēbēku'nqēlis lō'wa!
Assemble at your places all the men around the edge of the world

3. Hamats'alaqō'laē stamkнti ūwēsta'kqtis nā'la.
Hamats'a's voice is all around the world!

Kyimk·onā'kolastlas bēbēku'nqēlis lō'wa!
Assemble at your places all the men around the edge of the world

II. *Hā'mats'a.*

1. LēistāisELagyiliskya'sō!
He goes around the world, truly!

2. Hāmasaiā'lagyiliskya'sō!
For food he looks around the world, truly!

Laq wa'qsEnqēlis kya'tsis lō'wa.
Something on both sides of world, of heaven.

[1] This description supersedes the description formerly given in *Journ. Amer. Folk-Lore*, i. p. 58, ff.

3. K·'āk·ēk·atsā'la gyiliskya'sō!
He always wants truly!
much to eat on world;

Hāō, tlōkoa'la.
Hāō, the Tlōkoala.

Laq nanaqutsā'lisuqtis.
What he has been eating alone.

K·oē'sōtEnqēlis kya'tsis (lō'wa).
Far away at the edge of world, of heaven.

4. WaqsEnk·'asEla'gyiliskya'sō!
From both sides he eats on
world, truly!

Hāō, tlōkoa'la.
Hāō, the Tlōkoala.

Laq wimk·'asā'suqtis.
What he is not satisfied with.

Hēilky'ōtE'nqēlis kya'tsis lō'wa.
On the right side of world of heaven.

Translations: 1. Truly, he goes around the world!
2. Truly, he looks for food all over the earth, going on both sides of earth and heaven.
3. Truly, he wishes to eat plenty, the great Tlōkoala,[1] of what he found at the edge of the world.
4. Truly, now he eats with both hands, the great Tlōkoala, what did not satisfy him when he found it on the right side of the sun.

III. *Haialikyā'latl.*

1. Aia haia; haialikyā'latlk·uliskyastlala, Tlōkoa'la! Ts'ētsa'ēk·alak·uliskyastlala!
Aia haia; Haialikya'latl- noise, truly make! Tlōkoa'la! Ts'ētsā'ēk·a, noise, truly make!
Tlōkoa'la!
Tlōkoa'la!

2. Aia haia; lā'kyastlōistlas ēiwa'lakyastlōtl. Tlōkoa'la!
Aia haia; you, truly, will be the one, to you they will speak about their wishes. Tlōkoa'la!

3. Aia haia; lākyastlōistlas k·uitlaqa'laskyas. Tlōkoa'la!
Aia haia; you, truly, will be the one, the one they will untie. Tlōkoa'la!

4. *Aia haia;* lā'kyastlōistlas mā'mEntliakya'stlōtl. Tlōkoa'la!
Aia haia; you, truly, will be the one, you they will ask to give enough to eat. Tlōkoa'la!

[1] *Tlōkoala = Ha'mats'a*, the one who found his magic treasure.

Translation: 1. Aia haia! Sing Haialikya'latl, sing Ts'ētsā'ēk·a songs, Tlōkoa'la!
2. Aia haia! Then the people will ask you to fulfil their desires, Tlōkoa'la!
3. Aia haia! Then they will take the cedar-bark ornaments out of your hair, Tlōkoa'la!
4. Aia haia! Then they will ask you to give them plenty to eat, Tlōkoa'la!

IV. *Mā'mak·a.*

1. Hāu. Wä'ikyaslᴇ! dō'k·oatlakyas nāua'lakuas; iä!
Hāu. Go on! See his great nau'alak; iä!

2. Wä'ikyaslᴇ! dādōk·sᴇ'mēqs k·ā'mina!
Go on! Look after your sacred implement!

3. Häikya'smis wī'ōsūkuila k·ā'mina.
Truly it makes that they have no time to escape the sacred implement.

4. Häikya'smis ts'ētsak·wila nau'alak·.
Truly it shortens life the nau'alak.

Translation: 1. Hāu: Behold his great nau'alak; iä!
2. Be careful in swinging your sacred implement.
3. Truly it kills the people, so that they have no time to escape the sacred implement.
4. Truly, it cuts short their lives, the nau'alak.

NOTE.—*k·a'mina* is the name of the Mā'mak·a's stick, described on page 70. *Nau'alak·* designates any kind of dancing implement.

V. *Ō'lala.*

Olala sings: 1. K·'ālak·olistsuqtᴇn lēiʜtiʜlā'kyaatla ts'ēqpēk·ā'lagyilis.
The world knows me when I reached the dancing pole in the earth.

People sing: 2. K·'ᴇltitsᴇmā'aqus alʜ'aē'ems lōwa!
You are the bringer of the foundation of daylight!

3. Alō'mitsᴇmā'aqus alʜ'aē'ems lōwa!
You are the finder of the foundation of daylight!

4. K·'ōtitsimā'aqus k·'ōtk·ōtē'ems lōwa!
You reach to the earth pointing to heaven!

VI. *Tsē'k'ois* (=bird inside).

1. Ōmatatlā'lagyila k·ā'minatsē tsē'ak·os; iä!
Make silent! the sacred implement inside your great; iä!

2. Tlētlēqk·ä'lagyilitsuq, tᴇmi'lk·oatlalaQūs nau'alak· tsēak·os; iä!
Everybody names you, let it be still whistle your great; iä!

3. Tlētlēqk·alagyilitsuq ; haiatlilak·as.
Everybody names you ; medicine woman.

Translation :

Let the sacred voices in your body be silent, iä !
Everybody knows your name. Let your great whistle be still, iä !
Everybody knows your name, you great medicine woman.

VII. *Sī'l'is* (=*snake in belly*).

The people sing :

Hēiē, hēiē, ia. Sa'tsia sEnsk·ā'laitē !
Hēiē, hēiē, ia. How great our renowned man !

Ia. Sā'tsia sEnstlēk·alai'tē !
Ia. How great our named man !

Gyāpaqsalaētloq gyi'lEms nā'naualak·.
He comes in canoe the dreaded naualak.

Ia. Sā'tsia wista tlēk·alai'te !
Ia. How great he the named one !

Silis sings :

Kya nēkHsēwē'tikH kuā'kunqs'a'lagyitl Hayatlēlak·a'sō.
Kya, they say to me they counsel what to do for Hayatlēlak·a'sō.

Kya nēkHsēwē'tikH hamā'yaHilitsuq Iā'lagyilis.
Kya they say to me they treat very carefully Iā'lagyilis.

The people sing :

Ky'ē'slis nō'ntliek·alatl ! tlō'koitsē.
Don't be troubled ! great Tlōkoa'la.

Ky'ē'slis kyēkyalik·alatl ! tlō'koitsē.
Don't be afraid ! great Tlōkoa'la.

Kya gyī'k·ama gyiliskya'ska Sī'siutlkyas tlō'koitsē k·'alai'tē.
Kya chief the very first is the true Sisiutl, you great Tlōkoa'la that you are named.

VIII. *Yiā'iatalatl.*

1. Iā'haha hana. Haikya'smis ts'ātsek·ēnōetgyī'tl.
Iahaha hana. Truly, that is why they dance with you.

2. K·'ē'nkui'lisus amīaqai'kyasō.
For that of which you have plenty in your hands you are praised.

3. K·ais ye'tEnikui'lisus.
Because of the rattle in your hand.

4. TsElōak·aitkya'sō.
Your name is called.

IX. *Lōlō'tlalatl.*

1. Ia'qāma ia lau qā'ma gya'qEn ō'laiE kyasōtl.
Iaqā'ma ia lau qā'ma I come ? ?

2. Tlatlēk·ēla′lait.
Everybody calls your name.

3. Wīkyū′stoa sūtlō′q lēlâ′alēnoq.
You cannot contend against the name lâlēnoq.

4. Māmentlēaskyastloq lēlâ′alēnoq.
They will always be satisfied by your supply of food lâ′lēnoq.

X. *Wā′tanum.*

1. Wīqsēlē′stoq; ts' ētl'u′mistālis.
He did not go in boat; this news is spread everywhere.

2. Wīqsēlē′stoq; tlēqk·u′mistālis.
He did not go in boat; this name is spread everywhere.

3. Gyi′lEmkyastlus nanâ′alak·.
You will be feared, Naualak·.

4. Atsâ′kyastlus gyilEmkyastlus nanâ′alak·.
Oh, wonder you, you will be feared, Naualak.

NŌNTLEM SONGS.

I. *Ia′kHim* (=*badness*). *Mask, fig.* 19.

K·'ā′qōlitsētlala Ia′kHim sHpa′ni.
He will rise the great Ia′kHim from below.

P'ō′lik·olā′maseita Ia′kHim aski nā′la; nā′nsgyitala.
He makes the sea boil, the Ia′kHim of the world; we are afraid.

Iayakilatla Ia′kHim aski nā′laiē; latsk·tlālatl.
He makes the face of the sea bad the Ia′kHim of the world; we shall be afraid.

Iak·amgyustâ′latl k·'a′qola-utlē Ia′kHim aski nā′laiē.
He will throw up blankets out of the salt water, the Ia′kHim of the world.

II. *Sī′siutl* (*the double-headed snake*). *Song probably incomplete.*

Sasislā′itia! SEns gyīk·emaikya′sō Sī′siutllaitlē.
How wonderful! Our very chief dances as Sisiutl.

SEns gyīk·emaikya′sō ia lamlau′isōq māqsalisātl nEmsk·ama lē′lk·olatlē.
Our very chief ia he is going to swim in half one tribe. (= *to destroy one half*)

III. *Nūtlematl. Song probably incomplete.*

Waiē ai′tsikyasōtl! tlēaanā′lagyilitsumkya′sō.
Waiē oh wonder! He makes a turmoil on the earth.

Aitsikyasōtl! sāoltalagyilitsumkya′sō.
Oh wonder! He makes the noise of falling objects on the earth.

Gyōqgyōqk·oalagyilitsumkya′sō.
He makes the noise of breaking objects on the earth.

IV. *Tsōnō'k·oa.*

'Halselau'qten wī'tsumgyila hā'amutisa hā'amutisa.'
'I almost not in time for rest of food on beach. for rest of food on beach.'

Ialagyilis lEq nā'la haitsē k·'ā'maqōtl tlā'wisilak'.
Continuing in the world the great one always made to stand.

Waiatigyīlak', kuē'qagyilak'.
Made to pity none, made to kill.

Gyā'qtlēq wiwangyilatlōtl lēlqoala'tlē.
You come to make poor the tribes.

I.e., Tsōnō'k·oa:
'I was almost in time to see them eating on the beach.'

Chorus:
You are the giant who always stands upright in the world,
You are made to pity nobody, you kill everybody;
You come to impoverish the people.

V. *Nūn* (=*black bear*).

Hai'ōō' a hai'ioō'! Tlē'k·atsē'lalaikya nanqatsēla laikya!
Hai'ōō' a hai'ioō'! Call your great name called great bear let you!

Lā'tlaoq hayi'mk·ama tlak·ē' la tlētlek·amnu'qsis ē'iatlala na'nkyasō.
He is going straight to the first the first who have names among your enslaved tribes verily bear!

Sā'qautlasE'ntsia qōmatlatlā'sia.
Then we shall have a war.

Sā'qautlasE'ntsia tsīnaQua'latlā'sia.
Then we shall have trouble.

I.e., Haiōō' a hai'ioō'! Let your great name be called, great bear!
You will at once kill the chief of the tribes who become your slaves, great bear!
Then we shall have a war.
Then we shall have trouble.

VI. *Wolf.*

Iaiī'kalak·oala hā'is gyasengyaq wa'wakulītla. Wē'kyētlus ē'telis
Noise of giving away blankets. they will come and make noise barking in the house. You will again

k·'oa'qēlis walas tEmna'qoa; k·'uliakuä'gyilis stis gyīgyīk·a'ma.
grow as great as you were always; you oldest on earth of all chiefs.

Yī'heyi.
Yī'heyi.

Auila'laē watltE'mas atla'nEmas gyīgyīk·a'maē! niHilä'k·nts
Wonderful the words of the wolves of the chiefs! they say: we (come)

gyinlī'kyelē	p'äp'ayiā'latl	p'esagyī'la	p'esagyī'la,	mā'qoagyila
together with children	*to promise to give away blankets*	*to give away blankets*	*to give away blankets*	*to give away many blankets*

moqsista'lis'a	lēilk·oā'atlē.	Yī'heyi.
to give away blankets to everyone	*tribes.*	*Yī'heyi.*

WäHsala	iautlemē'tl	ātlā'nEma	gyīgyīk·a'maē	atlō'q'ē	k'oē'gyilisa
Try	*to make him mild*	*of the wolves*	*the chiefs*	*that it may not*	*something happen*

QuaQuē'gyi'lisa	wä'lagyila	nEmā'lisila	k·amē'lēk·agyīla.	Yīheyi.
(moving his tail?)	*make short life*	*make short lived*	*make people fall dead together.*	*Yīheyi.*

I.e., The chiefs of the wolves will come and bark in the house, giving away blankets. You will always be one of the greatest, you! the oldest of all the chiefs of the world. Yīheyi.

Wonderful are the words of the chiefs of the wolves. They say: We shall all assemble with our children, to the promise to give away blankets, to the giving away of blankets to all the tribes of the world. Yīheyi.

Let us try to make them mild the chiefs of the wolves, that he may not unexpectedly shorten our lives and kill all of us by moving his tail. Yīheyi.

VII. *Kuniqua.*

Kunquakyastlēqk·ae.	Sā'kyastlasē ku'nquakyasō.
Verily! it will thunder loud for him.	*Oh! wonderful will be that thunder.*

VIII. *Qō'los (a species of eagle).*

K·oā'laHits	ha'winalanak·	Ts'ē'k·oa	cEns	gyī'k·amāē	qō'loskyasō
Let us not	*frighten him*	*Ts'ē'k·oa*	*our*	*chief*	*the wonderful eagle*

k·oā'latlala	nāk·otliō'is	Ens	nā'la.
sitting down on top of	*the middle of*	*of the*	*sky.*

I.e., Let us not frighten him the great bird, our chief, the wonderful eagle, who sits down in the middle of the sky.

IX. *Henkyaqstâla or Kitâ'qolis.*

Yā'lamlā'wisEns	nEmā'lamenē'qom	Quā'nēk·E'lEqtlē	ōmagyilak'sEns
It is said that we will	*together the small ones*	*move heads in dancing after him*	*who is made our chief's son*

nEmts'aqkē'alisē.
the only greatest one.

Mā'sē	wā'tldEms	Nū'tlEmgyila?
What is the word of		*Nūtlemgyila?*

Haiqo wā'tldEms Nū'tlEmgyila nEmts'aqk·ē'alisē.
That is the word of Nū'tlEmgyila the only greatest one.

I.e., It is said that we, the unimportant people, shall dance after him who is made the son of our only greatest chief.
What said Nū'tlEmgyila?
Thus spoke Nū'tlEmgyila, the only greatest chief.

X. *Tlē'qalaq.*

Gyā'qEn tlē'k·anōmutl tlēqtlēk·ā'ita Wina'lagyilis.
I come to name you named by all Wina'lagyilis.

Gyā'qEn; k·'amtEmōtltōlā'lagyilitsus Wina'lagyilis.
I come; he throws a song out of boat on land Wina'lagyilis.

Gyā'qmēsEn; ha'nk·Emlisasus Wina'lagyilis.
I have come; it lands Wina'lagyilis.

Gyā'qen; kyaqotltâ'lisaisus tsē'qēoēgyilis Wina'lagyilis.
I come; he brings me out of boat his dancing cap Wina'lagyilis.

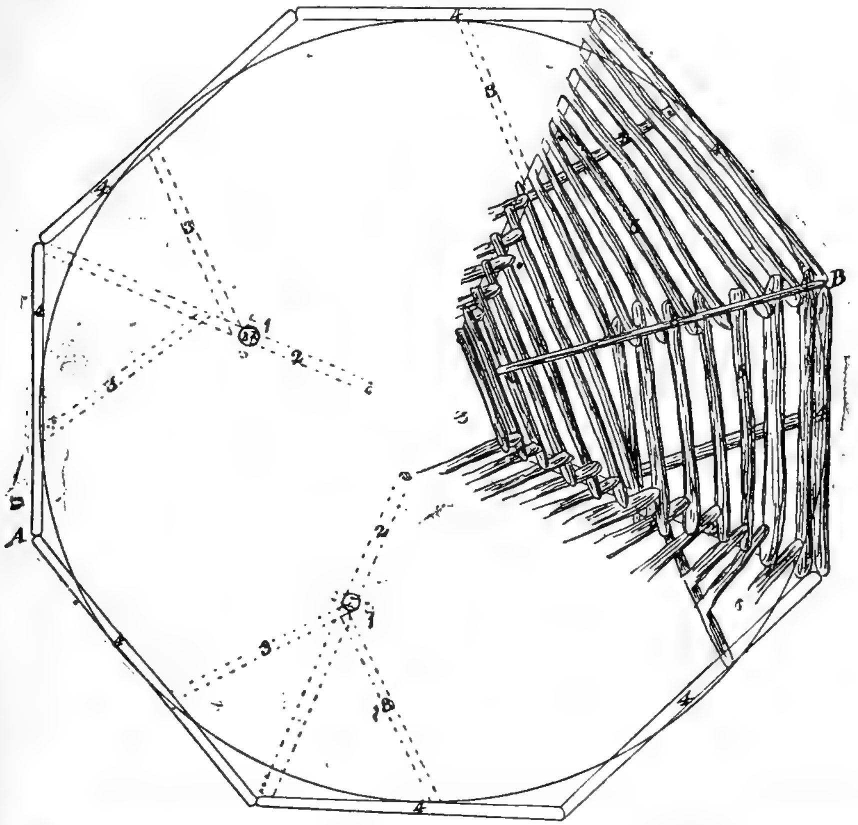
IV. THE SHUSHWAP.

The ancient customs of the Salish tribes of the interior of the Province of British Columbia have almost entirely disappeared, as the natives have been christianised by the endeavours of Catholic missionaries. Only a very few still adhere to their former customs and usages; for instance, a group of families living in Nicola Valley and another on North Thompson River. I did not come into contact with any of these, and consequently the following remarks are founded entirely on inquiries. I selected the Shushwap as an example of the tribes of the interior. The customs of the Ntlakyā'pamuQ, Stlā'tliumQ, and Okanā'k·ēn differ very slightly from those of the Shushwap, if at all. The information contained in the following chapter has been collected at Kamloops. The proper name of the Shushwap is Sū'QuapmuQ or SeQuapmuQ. The district they inhabit is indicated on the map accompanying this report. They call the Okanā'k·ēn Setswa'numQ, the carriers Yū'nana, the Chilcotin PEsqä'qEnEm (Dentalia people), and the Kutonaqa Sk·ēsē'utlk·umQ. The organisation of the tribe is similar to that of the southern branches of the Coast Salish, as described on p. 569; that is to say; the tribe is divided into a great number of septs, or, as we might say more properly, in the present case, village communities. While on Vancouver Island these septs bear still a limited similarity to the gentes of the northern coast tribes, this is no longer the case on the mainland. The Ntlakyā'pamuQ, Stlā'tliumQ, Shushwap, and Okanā'k·ēn are subdivided in the same way; but besides this the tribes speaking the same language are comprised under one name. I shall not enumerate the villages of these tribes, as my lists are far from being complete.

Houses and Lodges.

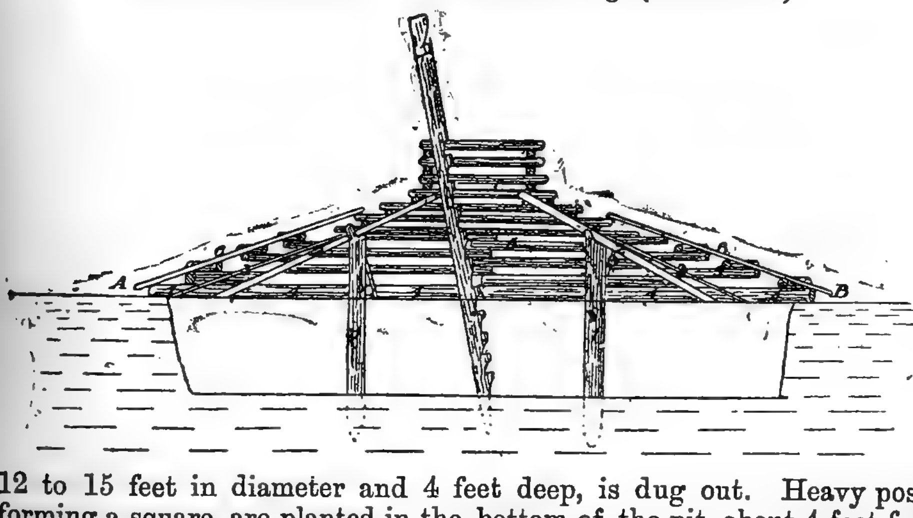
The characteristic dwelling of these Indians is the subterranean lodge, generally called in the Jargon '*keekwilee-house,*' *i.e.*, low or underground house. It was used by all the Salish tribes of the interior, and spreads as far down Fraser River as the mouth of Harrison River, where

FIG. 20.—Plan of Subterranean Lodge and Construction of Roof.



both the large wooden house of Vancouver Island and the subterranean lodge are in use. The latter is built in the following way. A pit, about

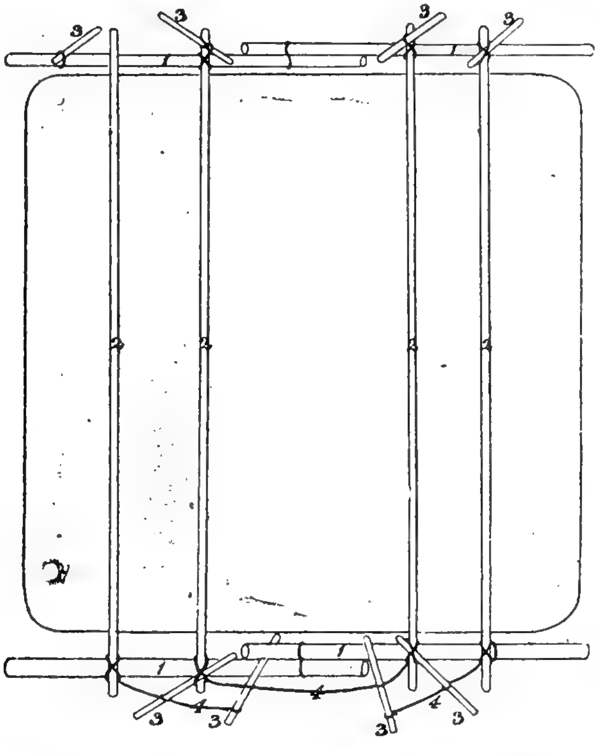
FIG. 21.—Elevation of Subterranean Lodge (Section A B).



12 to 15 feet in diameter and 4 feet deep, is dug out. Heavy posts, forming a square, are planted in the bottom of the pit, about 4 feet from

its circumference. These posts (1, figs. 20, 21) are about 6 or 7 feet high, and have a fork formed by a branch at their top, in which slanting beams rest (2), running from the edge of the pit over the fork to the centre, which, however, they do not reach. These beams consist of trees split in halves, and support the roof. Next, poles are laid from the edge of the pit to these beams, one on each side (3). Then heavy timbers are laid all around the pit; they are to serve as a foundation for the roof and run from the beams along the slanting poles (4). Thus the whole building assumes approximately an octagonal form. On top of these timbers other timbers or poles are laid, the shorter the nearer they approach the centre of the pit and the higher parts of the beams (2) on which they rest. They are laid alternately on adjoining sides of the octagon, so

FIG. 22.—Plan of Winter Lodge.

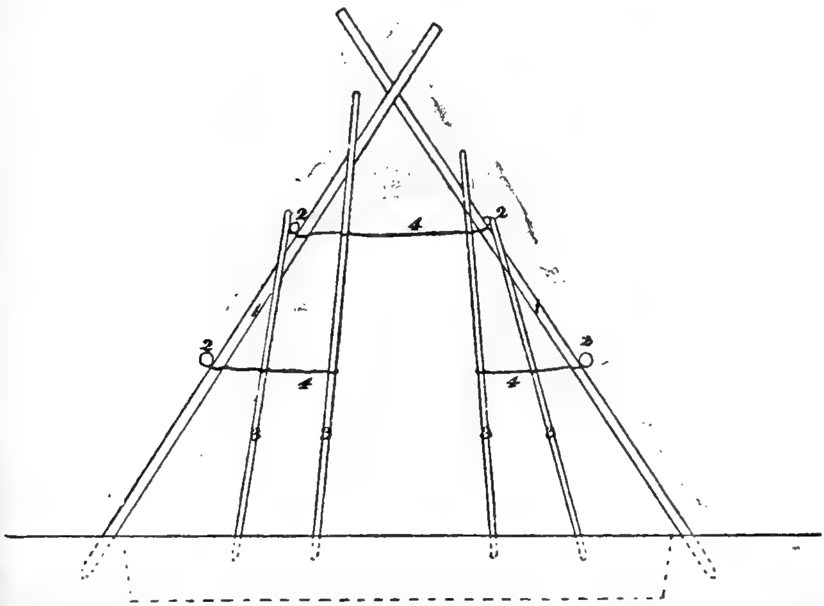


that the poles of one side always rest on the ends of those of the neighbouring sides. This framework is continued up to the ends of the beams (2). Here a square opening or entrance-way, of the form of a chimney, is built, the logs being placed on top of each other in the same way as those of a log cabin. The whole roof is covered with bundles of hay, which are kept in place by means of poles (6) laid on top of the roof, between the beams. Finally, the whole structure is covered with earth. A ladder cut out of a tree ascends into the entrance, the steps being cut out of one side and going down to the bottom of the pit. The upper extremity of the ladder is flattened at both sides and provided with a notch, which is used for tying the moccasins to it which are not taken inside the dwelling. The fire is right at the foot of the ladder; the beds are in the periphery of the dwelling, behind the posts (1).

Another kind of winter lodge is built on the following plan: A hole, about 18 inches deep, is dug. It is about 12 feet long and 8 or 9 feet wide, with rounded corners. In the front and the rear—that is, at the narrower ends—pairs of converging poles are erected (1, figs. 22, 23). They are connected by two cross-bars on each side (2). In the front and the rear four or more slender poles are tied to the converging poles and planted into the ground, so that they form a slight curve in the front and in the rear of the lodge (3). They are steadied by means of wickers (4). The lower part of this structure is covered with bundles of hay, the upper part with a double layer of mats made of rushes. The ridge remains open and serves as a smoke-escape. In some instances the hut is covered with bark.

The temporary summer lodge consists merely of three or four converging poles, connected by wickers, and covered with mats made of bullrushes—much more usually a complete criss-cross of branches running

FIG. 23.—Front Elevation of Winter Lodge.



in two directions, six or eight sticks each way. It differs in no essential from sweat-houses used all over the northern interior of the continent.

The sweat-house is always used when a person has to undergo a process of ceremonial cleansing. It is built on the bank of a creek and consists of two stout willow branches, crossing each other, both ends being planted into the ground. It is covered with skins. The door is at the foot of one of these branches and can be closed by a piece of skin.

The principal method of fishing is by means of bag-nets. Platforms are built, projecting over the river. On these the fishermen stand, provided with a large bag-net. Salmon are also caught with the spear. The fish are dried on platforms, which are erected on the steep banks of the rivers, the lower side being supported by two pairs of converging poles, the upper resting on the ground. Venison is dried on platforms of a similar description. Provisions are stored, either in small sheds which stand on poles, about 6 feet above the ground, or in caches. If venison is to be dried very quickly it is hung up in the sweat-house (see below).

The clothing of the natives was made of furs or of deer skin. I am unable to give a satisfactory description, as I have not seen any. Women wear dentalia in the perforated septum of the nose. Men and women wear ear-ornaments of shells or teeth all around the helix. Both men and women were tattooed, the designs consisting of one or three lines on each cheek and three lines on the chin. So far as I could make out there is no connection between this custom and the reaching of puberty. In dancing the face is painted with designs representing sun, moon, or stars, birds or animals. They may take any design they like. The hair is strewn with eagle-down.

Deer-skins are prepared in the following way: The skin is soaked in a brook or in a river for a week. Then the hair is removed with a knife. The hind-feet are next tied to a stick, which the worker holds with his feet. Another stick is pushed through the fore-feet, which are also tied together, and the skin is wrung out and dried. When it is dry, water is made lukewarm, and the brains of a deer or any other animal are mixed with it. This mixture is spread over the dry skin, which is then wrung out once more, and worked with a stick, to the end of which a stone scraper is attached. Now a pit is dug, the bottom of which is filled with rotten wood. The latter is ignited, and both sides of the skin are smoked over the burning wood for a short time, the skin being stretched over the pit. Finally, it is washed in clear water and dried. It is believed that the smoking process has the effect of preventing the skin from becoming hard after getting wet. The skins of bucks and does are considered equally good; they are best in the autumn.

The Shushwap do not know the art of pottery, and do little, if any, carving in wood. Their household goods are made principally of basketry, in which they excel. Basketry of the Shushwap and Ntlakyapamuq is sold extensively to the tribes of southern Vancouver Island. Their baskets are made of roots of the white pine. The roots are dyed black with an extract of fern root; and red with an extract of alder-bark or with oxide of iron. Very beautiful patterns are made in these three colours. Baskets are used for storing, carrying, and cooking provisions.

The Shushwap make mats of bulrushes, which are strung on threads of nettles, in the same way as the Lku'ñgen and their neighbours do. Mats are also plaited, threads made of nettles being braided across bulrushes.

Fire was obtained by means of the fire-drill, rotten willow roots being used for spunk. In travelling they carried glowing willow roots.

Canoes are made of cotton-wood, cedar, or in rare instances of bark. For working wood stone hammers and wedges were used. In hunting expeditions they cross rivers on rafts made of rushes or on logs. In winter snow-shoes are used on hunting expeditions. There are two patterns, one imitating the shape of a bear's foot. The former consists of a frame of bent wood, with a cross-bar near its broad end. Thongs run from this bar to the front, like the toes of a bear's foot, and a network of thongs runs back from the bar, filling the hind part of the frame. The balls of the toes rest on the cross-bar. The other pattern consists of a long frame of bent wood, the point of which is turned up. There are two cross-bars near the centre in front of which the foot rests. The front and rear ends are filled with a network of sinews.

Deer were hunted with the help of dogs. In the autumn, when the deer cross the lakes and rivers, they were driven by hunters and dogs to a certain point, where others lay in waiting with their canoes. As soon as the deer took to the water they were attacked by the canoe-men.

Dentalia and copper bracelets served as money. The former were obtained by trade from the Chilcotin, who for this reason had the name Psqä'qENEm, *i.e.*, dentalia people. In exchange, the Shushwap gave dressed deer-skins and, probably, in late times, horses. They traded the dentalia they had received from the Chilcotin to the Okanā'k·ēn for horses. Trade was also carried on with the northern Tinneh tribes, especially the Carriers. There was no communication with the Lower Fraser River on account of the prevailing hostility between the tribes of these regions. Copper was obtained, partly by trade, but some was dug by the natives themselves. There was a digging at Kamloops Lake, which was worked up to the last generation, when a man was killed by a fall of rocks which buried the mine. Since that time it has never been worked.

Food was boiled in baskets, which were filled with water that was made to boil by throwing red-hot stones into it. Roots are cooked in the following way: A hole is made in the ground, and red-hot stones are thrown into it. These are covered with willow twigs and grass. A stick is placed upright in the centre of the pit and the roots are laid on top of the grass around the stick. They are covered with more grass and the hole is filled up with earth, so that part of the stick remains projecting out of it. Then water is poured out, so that it runs down the stick into the hole, and on touching the red-hot stones produces steam. Finally, a fire is built on top of the hole. The belief prevails that the roots must be cooked in this particular way by women only, and early in the morning, before they have taken any food, as else they could not be properly done. No man is allowed to come near the place when they are being steamed.

There is no fixed time for meals. Hunters who leave early in the morning take breakfast before leaving, their wives eating after they have gone.

The reports on social organisation which I obtained from my informants are very meagre. Each of the numerous tribes of the Shushwap had its own chief. The people are divided into nobility and common people. Common people can, on account of bravery or wealth, attain high rank, but cannot become noble, as nobility is hereditary. There is no indication of the existence of gentes. The family is 'paternal.' The chieftaincy is also hereditary. The chief is naturally a member of the nobility. At the death of the chief his eldest son or, if he has no son, his younger brother, succeeds him at once. The affairs of the whole tribe are governed by the chief and a council of the elders. Among the prerogatives of the chief I heard the following: When the first salmon of the season are caught, or when the first berries are picked or the first deer killed, no one must eat of it until it has been presented to the chief, who must pray over it and partake of it. It did not become quite clear from the statements of my informants whether this is entirely a religious function, or at the same time a tribute. It is certainly of interest to see that here, as well as among the Nootka, we find certain religious functions vested in the chief. At the time when the berries begin to ripen an overseer is set [by the chief?] over the various berry patches, whose duty it is to see that nobody begins picking until the berries are ripe. He announces when the time has come, and on the next morning the whole tribe set out and begin to pick berries, the field being divided up among the tribe. After they are through picking, the berries are divided among the families of the tribe. The chief receives the greatest portion. In the same way an overseer is set over the salmon fisheries, and the catch is divided among the whole tribe. It seems that the various tribes of the Shushwap had no separate hunting grounds, but that they hunted over the whole territory, wherever they liked. I do not think, however, that the fisheries and berry patches belonged to the whole people in common. Disputes arising between members of the same tribe were generally settled by arbitration. For instance, where a number of men had driven deer into a lake and a dispute arose as to who had driven one particular deer, an arbitrator was appointed, who had to track it and whose decision was final. The old were well treated and respected. In some instances when a man believed himself slighted he would commit suicide.

The tribes and families had separate hunting grounds originally. The custom still holds to some extent among the Nicola Indians, but is now almost forgotten by the Kamloops people.

The chief was not leader in war, the war-chief being elected among the 'braves.' The hostile tribes would meet, but sometimes, instead of a battle between the whole parties taking place, the war-chiefs would fight a duel, the outcome of which settled the dispute. Their weapons were bow and arrow; a lance; a bone club with a sharp, sabre-like edge; a stone axe having a sharp point, the stone being fastened in a perforated handle; and a stone club, consisting of a pebble, sewed into a piece of hide, and attached to a thong, which was suspended from the wrist. They protected themselves with armours of the same kind as those used on the coast—coats made of strips of wood, which were lashed together, or jackets of a double layer of elk-skin, and a cap of the same material. In time of war a stockade was made near the huts of the village. A cache was made in it, and baskets filled with water were kept in it. When an attack of the enemy was feared, the whole population retired to the stockade, the walls of which were provided with loopholes. Captives made in war were enslaved. At the end of the war, captives were frequently exchanged.

The following tale of a war may be of interest. One summer, about eighty years ago, the Sekā'umq, who live near the head waters of North Thompson River, stole two Shushwap women at Stlie'tltsuq (Barrière) on North Thompson River. Their brothers pursued the Sekā'umq, but were unable to overtake them. In the fall, when the snow began to cover the country, they started out again and soon found the tracks of their enemies, who were travelling northward. One of the women wore, at the time when they were surprised by the enemies, a white-tail deer blanket. She had torn it to pieces and put them into split branches of trees, which she broke and turned in the direction in which they were travelling. The Shushwap found these, and knew at once that they were on the right track. Finally the Shushwap reached a camp which the Sekā'umq had left on the same morning. They followed them cautiously. While they were travelling a troop of deer passed close by, and they wounded one of them with their arrows. Among the party of the Sekā'umq was a blind old man, who was led by a boy, and, as he was not able to walk as fast as the others, followed them at some distance. The wounded deer ran past them and the boy observed the Shushwap arrow.

He cried: 'There is a deer that has been struck by a Shushwap arrow.' The old man at once despatched him to the main party, and told him to inform the chief of what he had seen. The boy obeyed, but the chief did not believe him. He merely made a gesture indicating that the Shushwap would not dare to show their backs in this country. (He closed the thumb and the third and fourth fingers of his right hand, bent the first and second fingers towards the thumb, holding them apart, the palm directed towards his face.) The two women heard what was going on. They thought that their brothers might have followed them, and at nightfall went back to see whether they might discover anyone. They met the Shushwap, who instructed them to keep their husbands—for they had been married to two men of the Sᴇkā'umq—awake until early in the morning. They obeyed, and when the men had fallen asleep in the morning the Shushwap made an attack upon the camp and killed all but three, who had succeeded in putting their snow-shoes on and fled. The Shushwap pursued them, and one of the Sᴇkā'umq jumped into a hole formed by the melting of the snow around a tree. From his hiding place he wounded a Shushwap called Tā'leqän, when passing by. Two of the fleeing Sᴇkā'umq were killed, the third escaped. Tā'leqän died of his wound when they were returning homeward. His body was burnt and his bones taken along, to be buried in the burial ground of his native village.

Sign Language.

On the coast of British Columbia the extensive use of the Chinook jargon has almost entirely superseded the use of the sign language; but there is little doubt that it has been in use in former times. The only instance of the use of signs—except in making tales more vivid and graphic —that came under my observation was when an old Haida, who did not understand Chinook, wanted to tell me that he could not speak the jargon. He introduced the first finger of his right hand into his mouth, acted as though he attempted to draw out something, and then shook his finger.

In the interior of the province the sign language is still used extensively. The following signs were collected among the Shushwap.

1. *All.*—Right hand held in front of breast, palm downward, moved around horizontally.

2. *Bear.*—Both fists held in front of breasts, knuckles upward, the thumbs touching the bent first fingers; fists pushed forward alternately in circular motions, imitating the movements of a bear.

3. *Bear's hole.*—Second, third, and fourth fingers of both hands closed; thumbs and first fingers extended, points of both thumbs and of both first fingers touch, so that they form a circle.

4. *Beaver.*—Right hand drops, palm downward, between the extended thumb and first finger of left, so that the wrist rests on the interstice. Imitation of beaver's tail.

5. *Boy, about fifteen years of age.*—Open hand raised in front of breast to the height of the chin, palm turned toward face.

6. *Bush.*—Open hands placed against each other, so that both thumbs and both fourth fingers touch.

7. *Daylight.*—Hands half opened, first finger slightly extended held upward in front of body, palms inward at height of chin, hands then moved outward, describing circles.

8. *Deer.*—Hands held up on both sides of head, at height of ears, palms forward, open.

9. *Deer running.*—Fists held in front of breast, knuckles upward, striking out alternately and horizontally full length of arms.

10. *Doe.*—Hands brought up to ears, thumb, third and fourth fingers closed, first and second extended backward, touching one another, back of hand upward.

11. *Fish.*—Hand stretched out, held horizontally in front of breast, palm downward, moving in quick wandering motions in horizontal plane.

12. *Many fish.*—Both hands held in the same way as last, one above the other, but fingers slightly spread, both hands performing wandering motions.

13. *Girl.*—Both hands, half opened, held not far from shoulders, palms forward, then suddenly pulled back to shoulders.

14. *Horse.*—Thumb, third and fourth fingers closed, first and second extended horizontally, parallel to breast, touching one another.

15. *I do not understand.*—Palms clapped on ears, then hands taken off and shaken.

16. *Lake.*—Hands held before breast close together, fingers describe a wide circle forward and back to breast.

17. *Nightfall.*—Both hands held slightly bent in front of breast, palms downward, then moved downward.

18. *Noon.*—Right hand closed, first finger extended, held up in front of face.

19. *Old man.*—First finger of right hand held up, slightly bent, the other fingers being closed, indicating the bent back.

20. *Quick.*—Right arm pushed upward and forward, slightly to the right, at the same time left fist striking breast.

21. *Rider.*—First and second fingers of right hand straddling the first and second of the left, which is held in the position of 'horse.'

22. *Rock.*—Both fists held up in front of face, knuckles towards body, struck together and separated again.

23. *To run.*—Elbows close to body, lower arms held horizontally, hands closed.

24. *Stop.*—Hand raised, open palm forward, then shaken.

25. *Sunrise.*—Right hand half opened, first finger slightly extended upward, palm towards body, then moved upward.

26. *Sunset.*—First finger pointing downward in front of breast and moved downward.

27. *Trap.*—Both palms clapped together.

28. *Young man.*—As 'Boy,' but hands raised higher.

See also pp. 638, 639.

For indicating the direction in which a party travels, poles are planted into the ground, pointing in that direction, or twigs of brushes or trees are broken and pointed in the same way. A pole directed toward the part of the sky where the sun stands at a certain hour indicates at what time something is to be done or has been done. Figures of men drawn on the sand indicate how many have been killed by a war party. A number of hairs from a horse's mane indicate the number of horsemen that passed by. Such messages are left particularly at crossings of trails.[1]

[1] See Fifth Report, p. 836.

Fires are used to give signals to distant parties.

A number of rock paintings are found on the shores of Kamloops Lake. I have not seen them, and do not know what they represent.

Games.

The games of the Shushwap are almost the same as those of the coast tribes. We find the game of dice played with beaver-teeth (see p. 571), and the well-known game of lehal. Children and women play 'cat's cradle.' A peculiar gambling game is played in the following way: A long pole is laid on the ground, about fifteen feet from the players; a ring, about one inch in diameter, to which four beads are attached at points dividing the circumference into four equal parts, is rolled towards the pole, and sticks are thrown after it, before it falls down on touching the pole. The four beads are red, white, blue, and black. The ring falls down on the stick that has been thrown after it, and, according to the colour of the bead which touches the stick, the player wins a number of points. Another gambling game is played with a series of sticks of maple wood, about four inches long, and painted with various marks. There are two players to the game, who sit opposite each other. A fisher-skin, which is nicely painted, is placed between them, bent in such a way as to present two faces, slanting down toward the players. Each of these takes a number of sticks, which he covers with hay, shakes and throws down one after the other, on his side of the skin. The player who throws down the stick bearing a certain mark has lost.

Shooting matches are frequently arranged. An arrow is shot, and then the archers try to hit the arrow which has been shot first. Or a bundle of hay or a piece of bark is thrown as far as possible, and the men shoot at it. The following game of ball was described to me: The players stand in two opposite rows. A stake is driven into the ground on the left side of the players of one row, and another on the right side of the players of the other row. Two men stand in the centre between the two rows. One of these pitches the ball, the other tries to drive it to one of the stakes with a bat. Then both parties endeavour to drive the ball to the stake on the opposite side, and the party which succeeds in this has won the game.

Customs regarding Birth, Marriage, and Death.

My information regarding customs practised at the birth of a child is very meagre. The navel-string is cut with a stone knife. The child is washed immediately after birth. The custom of deforming certain parts of the body does not prevail. The mother must abstain from 'anything that bleeds,' and consequently must not eat fresh meat. There are no regulations as to the food or behaviour of the father. The cradle after being used is not thrown away, but hung to a tree in the woods. If a child should die, the next child is never put into the same cradle which was used for the dead child.

A girl on reaching maturity has to go through a great number of ceremonies. She must leave the village and live alone in a small hut on the mountains. She cooks her own food, and must not eat anything that bleeds. She is forbidden to touch her head, for which purpose she uses a comb with three points. Neither is she allowed to scratch her body, except with a painted deer-bone. She wears the bone and the comb suspended from her belt. She drinks out of a painted cup of birch-bark, and neither more nor less than the quantity it holds. Every night she walks about her hut, and plants willow twigs, which she has painted, and to the ends of which she has attached pieces of cloth, into the ground. It is believed that thus she will become rich in later life. In order to become strong she should climb trees and try to break off their points. She plays with *lehal* sticks that her future husbands might have good luck when gambling.[1]

Women during their monthly periods are forbidden to eat fresh meat, but live principally on roots. They must not cook for their families, as it is believed that the food would be poisonous. During this time the husband must keep away from his wife, as else the bears would attack him when he goes hunting.

A man who intends to go out hunting must keep away from his wife, as else he would have bad luck. They do not believe that the wife's infidelity entails bad luck in hunting and other enterprises.

Women must never pass along the foot or head of a sleeping person, as this is unlucky.

Women who are with child must not touch food that has been touched by mice, or eat of a plate which a dog has licked off. If she should eat a bird that has been killed by an animal her child would be subject to dizziness.

The marriage ceremonies were described to me as follows: A young man who wishes to marry a girl takes a number of horses and other property that is considered valuable and offers it to the father of the girl he wishes to marry. The latter, before accepting the price offered, invites his whole family to a council and asks their consent. If they agree to accept the suitor and the price he has offered for the girl they tie the horses to their stable, and take the other goods into the house, as a sign of their willingness. After this the young man may take the girl without further ceremonies. After the marriage the bridegroom and his family go on a hunting expedition, and try to obtain as much game as possible, which is to be given to his father-in-law. The latter dresses the meat and invites the whole tribe to a feast. Then he and his family in their turn go hunting, and present the game they have obtained to the young man's father, who gives a feast to the whole tribe. At this time the girl's father returns all the payments he has received to the young man's father. For a number of days the couple live with the girl's family. When the young man goes to reside with his wife he asks all his friends to support him, and they give him presents of food and clothing. The latter he puts on, one suit on top of the other, goes to his father-in-law, and gives

[1] The following custom was described to me by Mr. J. W. Mackay, the Indian Agent for the Kamloops district. He heard it described at Yale, and therefore it probably belongs to the tribes of the Lower Fraser River. My inquiries at Kamloops regarding the custom were resultless. Mr. Mackay states that at the end of the puberty ceremonies the shaman led the girl back from her seclusion to the village in grand procession. He carried a dish called *tsuqtā'n*, which is carved out of steatite, in one hand. The dish represents a woman giving birth to a child, along whose back a snake crawls. The child's back is hollowed out and serves as a receptacle for water. In the other hand the shaman carries certain herbs. When they returned to the village the herbs were put into the dish, and the girl was sprinkled with the water contained in the dish, the shaman praying at the same time for her to have many children.

him all the property he carries. The latter distributes this property among the whole tribe according to the contributions everyone has made. Then the young couple remove to the young man's family, and before leaving her father's house the bride is fitted out with presents in the same way as the young man was when he came to reside with her family. This is a present to the young man's father, who also distributes it among the tribe. Marriages between cousins were not forbidden.

When a person died at the village the body was tied up in sitting posture, the knees being bent to the chin, and the arms tied together. A grave was dug, and its sides were rubbed with thorn bushes. Then the body was buried, and a number of poles were erected over the grave in the shape of a conical hut. The sand inside and around the hut was carefully smoothed. If on one of the following days tracks were seen in the hut, the being—animal or man—to whom they belonged would be the next to die. If after a while the sand should be blown away, the bones were buried again. Wherever they find human bones they clean them and bury them, thinking that others may do the same to their own relatives. When a person died far from home, for instance on a hunting expedition, the body was burnt, and the charred bones were carried home to be buried at the native village of the deceased. The report that the bones of the dead were washed regularly, which has been made by several travellers, seems to rest on these facts. No carved figures were placed over the graves, as was the custom on the Lower Thompson River. At the burial or the burning of the body, slaves, hounds, and horses of the deceased were killed. His favourite slaves were buried alive; the horses were eaten by the mourners, to whom a feast was spread on the grave. In some cases the uncle or nephew of the deceased would kill a number of his own slaves at the grave. Winter provisions, prepared by a woman before her death, were burnt. The clothes of a dead person must be washed before being used again.

A year after the death of a person his relatives collected a large amount of food and clothes, and gave a new feast on the grave. This was the end of the mourning period, and henceforth they tried to forget the deceased. At this feast his son adopted his name.

The relatives of a dead person during the mourning period must not eat deer, salmon, or berries, as else the deer and salmon would be driven away, and the berries would spoil. Their diet is confined to dried venison and fish. They cut their hair, and keep it short for one year, until the final feast is given. They must avoid touching their heads except with a stick or a comb. Names of deceased persons must not be mentioned during the mourning period. Men as well as women must go every morning to the river, wail, and bathe. When a man or a woman dies, the widow or widower is kept as a captive in the house of a brother-in-law. As soon as the mourning period, which in this case is particularly strict, is at an end, the widower must marry a sister or the nearest relative of his dead wife; the widow is married to her dead husband's brother, or to his nearest relative.[1]

Widows or widowers have to observe the following mourning regula-

[1] The mourning ceremonies of the Shushwap are evidently greatly influenced by those of their northern neighbours, the Carriers, which have been described by the Rev. A. G. Morice in the *Proceedings of the Canadian Institute*, 1889. The strictness of the levirate and the ceremonies celebrated at the grave are almost the same in both cases.

tions: They must build a sweat-house on a creek, sweat there all night, and bathe regularly in the creek, after which they must rub their bodies with spruce branches, the branches must be used only once, and are stuck into the ground all around the hut. The mourner uses a cup and cooking vessels by himself, and must not touch head nor body. No hunter must come near him, as his presence is unlucky. They must avoid letting their shadows fall upon a person, as the latter would fall sick at once. They use thorn bushes for pillow and bed, in order to keep away the ghost of the deceased. Thorn bushes are also laid all around their beds. A widower must not go hunting, as the grizzly bear would get his scent and attack him at once.

Various Beliefs.

Twins.—When twins are born, the mother must build a hut on the slope of the mountains, on the bank of a creek, and live there with her children until they begin to walk. They may be visited by their family, or any other who wishes to see them, but they must not go into the village, else her other children would die. Twins are called *skumku'mq-sisilt*, *i.e.*, young grizzly bears. It is believed that throughout their lives they are endowed with supernatural powers. They can make good and bad weather. In order to produce rain they take a small basket filled with water, which they spill into the air. For making clear weather they use a small stick, to the end of which a string is tied. A small flat piece of wood is attached to the end of the string, and this implement is shaken. Storm is produced by strewing down on the ends of spruce branches. While they are children their mother can see by their plays whether her husband, when he is out hunting, is successful or not. When the twins play about and feign to bite each other he will be successful; if they keep quiet he will return home empty-handed. If one of a couple of twins should die the other must clean himself in the sweat-house 'in order to remove the blood of the deceased out of his body.'

A decoction made of certain herbs, when used as hair-oil or mixed with the saliva of a person, acts as a love-charm.

To break eggs of the ptarmigan produces rain.

If one has a feeling as though someone was standing behind one's back, or if a sudden chill goes down one's back, it is a sign that someone will die. If one's leg twitches, someone is coming. When the ears ring, someone speaks ill of one. The owl cries *muk·tsä'k·* (he is dead), and calls the name of the person who will die.

One cannot make fire with the fire-drill after having eaten in the morning.

Hair that has been cut off must be buried or thrown into the river.

Beaver-bones (not those of the salmon, as is the custom on the coast) must be thrown into the river, else the beavers would not go into the traps any more. The same would happen if a dog should eat beaver-meat, or gnaw a beaver-bone.

When making bullets they mix wood that has been struck by lightning with the lead. They believe that the bullets thus become more deadly, as they will burn the deer's flesh.

They believe that the beaver, when constructing its dam, kills one of its young and buries it under the dam, that it may become firmer and not give way to floods.

Religion and Shamanism.

I received very scanty information only regarding the religious ideas of the Shushwap. Chiefs before smoking their pipes would turn them towards sunrise, noon, and sunset, after having them lighted, and thus offer a smoke to the sun, at the same time praying silently to him. The same custom is practised in British Columbia by the Kootenay. I did not find any other trace of sun-worship.

Souls do not return in newborn children.

When a person faints, it is a sign that a ghost pursues him.

The shaman is initiated by animals, who become his guardian spirits. The initiation ceremonies for warriors and shamans seem to be identical, the object of the initiation ceremonies being merely to obtain supernatural help for any object that appeared desirable. The young man, on reaching puberty, and before he had ever touched a woman, had to go out on the mountains and pass through a number of performances. He had to build a sweat-house, in which he stayed every night. In the morning he was allowed to return to the village. He had to clean himself in the sweat-house, to dance and to sing during the night. This was continued, sometimes for years, until he dreamt that the animal he desired for his guardian spirit appeared to him and promised him its help. As soon as it appeared the novice fell down in a swoon. 'He feels as though he were drunk, and does not know whether it is day or night, nor what he is doing.' The animal tells him to think of it if he should be in need of help, and gives him a certain song with which to summon him up. Therefore every shaman has his own song, which none else is allowed to sing, except when the attempt is made to discover a sorcerer (see p. 646). Sometimes the spirit comes down to the novice in the shape of a stroke of lightning. If an animal initiates the novice it teaches him its language. One shaman in Nicola Valley is said to speak the 'coyote language' in his incantations. Unfortunately, I did not learn the details of this language, so that I do not know whether it is a sacred language common to all shamans, or merely an individual invention. If the young man desires to become a successful gambler he must practise gambling while he is on the mountains. He throws the gambling sticks into the water while it is dark, and tries to pick them up again without looking. If he wishes to become a lightfooted runner he must practise running. It is said that one young man used to roll rocks down the slope of Paul's Peak, near Kamloops, and then ran after them until he was able to overtake the rocks, which leaped down the steep sides of the hill.

After a man has obtained a guardian spirit he is bullet and arrow proof. If an arrow or a bullet should strike him he does not bleed from the wound, but the blood all flows into his stomach. He spits it out, and is well again. 'Braves,' who have secured the help of spirits, are carried to the fighting ground. No woman must see them when on their way, as else they would lose their supernatural power. When an attack is going to be made on a village the guardian spirit of the warriors will warn them. In dreaming or in waking they see blood flying about, and this is a sign that someone will be murdered. Before going on a war expedition warriors would fast and abstain from sleep for a whole week, bathing frequently in streams. It was believed that this would make them nimble-footed.

Men could acquire more than one guardian spirit, and powerful shamans had always more than one helper. The principal duty of the shaman was to cure the sick. Disease may be due to a foreign body entering the body of a person, to disobeying certain rules, to the temporary absence of the soul, or to witchcraft. In all of these cases the help of the shaman is needed. The most important among the paraphernalia of the shaman is a headdress made of a mat, which is worn in his incantations. The mat is about two yards long by one yard wide. The corners of one of the narrow ends are sewed together, and it is put on as a headdress, the whole length of the mat hanging down the back of the shaman. Before putting it on they blow on it and sprinkle it with water which had been poured over magic herbs. As soon as the shaman puts on the headdress he 'acts as though he was crazy,' *i.e.*, he puts himself into a trance by singing the song he had obtained from his guardian spirit at the time of his initiation. He dances until he perspires freely, and finally his spirit comes and speaks to him. Then he lies down next to the patient and sucks at the part of the body where the pain is. He is supposed to remove a thong or a feather from it, which was the cause of the disease. As soon as he has removed it he leaves the hut, takes off his mat, and blows upon the object he has removed from the body, which then disappears. It is stated that in his dances he sometimes sinks into the ground down to his knees.

If the disease is produced by witchcraft or by disobedience to certain regulations, the shaman, during his trance, goes into the lower world, *i.e.*, underground, in order to consult with his guardian spirits. After a while he returns to the upper world and announces the cause of the sickness, saying that a woman passed by the head of the patient, or that the shadow of a mourner fell upon him, or giving some other imaginary cause of sickness. The most elaborate performance is the bringing back of absent souls. The Shushwap believe that while a man is alive the shaman is able to see the soul. After death the soul becomes invisible, although its movements may be heard. Therefore the shaman will sometimes lie down, the ear on the ground, and listen. If he hears a noise of a passing soul without seeing anything he will say: 'So-and-so has died. I heard his soul, but did not see it passing by.' If he sees it, it is a sign that the person to whom the soul belongs is sick, but may recover if his soul is restored to him. Then the shaman puts on his mat and begins his incantation. As soon as he has succeeded in summoning his spirit he sets out with him in search of the lost soul. While he is unconscious he runs and jumps, and is heard to speak to his spirit. He will say, for instance, 'Here is a chasm; let us jump across it!' He actually gives a jump and says, 'Now we have passed it,' &c. Finally he meets the soul, and is seen to have a severe fight with it until it is finally overcome. Then he returns in company with his spirit to the upper world, and throws off his mat as soon as he comes back. He restores the soul to the sick person by laying it on the crown of his head.

Sickness due to witchcraft is treated in the following way: When a shaman hates any person and looks at him steadfastly, he sends the latter's soul underground, to sunrise or sunset. The anger of a shaman may be aroused, for instance, by a young man who prides himself on his courage, and in order to show his undaunted spirit paints his face with figures, representing stars, sun, moon, birds, or any other designs that are considered becoming to the most powerful men of the tribe. After the soul has left the body of the young man another friendly shaman is called. He begins at once to sing all the songs of the shamans of the tribe. It is believed that as soon as he begins the song of the shaman who has bewitched the patient, the evil-doer will become crazy.

The shaman can also bewitch his enemy by throwing the cause of disease, *i.e.*, a feather or a thong, at him; or by putting magic herbs into his drink. Ground human bones, mixed with food, are believed to make the hair of the person who eats it fall out. If parts of the clothing of a person are placed in contact with a corpse the owner must die. It is believed that the shaman can in no way harm a white man.

The shaman also endeavours to obtain game in times of want. He begins his incantation and sends his soul in search of deer and other game. When he returns he tells the hunters to go to such and such a place in order to find the animals. When they find any they must bring the venison to the shaman. Nobody is allowed to eat of it until the shaman has eaten his share.

Frequently after a death has occurred the shaman is called by the relatives of the deceased. It is believed that the ghost of the dead person is eager to take one of his nearest relatives with him to the country of the souls. In order to drive the ghost away the shaman is called. He sees the ghost, and orders all the members of the mourning family to stay in the house, which the ghost cannot enter. Then he speaks to the ghost, asking him whom he wants, and telling him that he cannot have the person he wants. He appeases the ghost, who then leaves, and does not further trouble his relatives. The shaman is paid a high price for this service.

Contests between shamans, in order to ascertain who is the most powerful, are not rare. The one will take his charm first, blow on it, and throw it at the other. If the other is weaker he will fall on his back, and blood will flow from his mouth. Then the former blows on him and restores him by this means. They also practise jugglery. The shaman is tied, and he frees himself by the help of his spirit.

DEFORMED CRANIA FROM THE NORTH PACIFIC COAST.

In describing the customs of the Lku'ñgEN and of the Kwakiutl, mention has been made of the methods employed for deforming the cranium. It remains to say a few words regarding the effects of such deformations. So far as I am aware there exist three distinct types of intentional head deformation, which, however, are connected by intermediate types. These types may be designated as the Chinook, the Cowitchin, and the Koskimo, from the names of certain tribes practising these methods of deformation. The first is found in the region of Columbia River, principally among the Chinook and Cowlitz. Its northern limit is unknown to me. The second is practised on Puget Sound, by the Lku'ñgEN, Cowitchin, and Sk·qomic of British Columbia. The Catloltq form a gradual transition to the last type, which reaches its highest development at Kwatzino Sound, but extends southward along the coast of Vancouver Island and the mainland opposite to Toba Inlet and Comox. The Chinook cranium is excessively flattened (figs. 24 to 26), the forehead being depressed. The head is allowed to grow laterally. Consequently a compensatory growth takes place in this direction. The Cowitchin do not flatten the cranium, but rather shorten it by means of a strong pressure upon the region of the lambda and farther down. It appears that the subsequent flattening of the forehead is mainly due to growth under the altered conditions, after the compressing cushions have been removed.

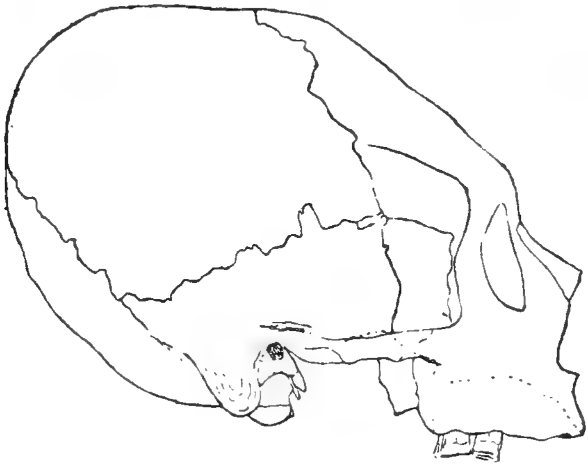
The third form of cranium is produced by combination of frontal, occipital, and lateral pressure. In crania of the southern tribes of this region, evidence of a pressure upon the lambda may be seen; but the forehead is at the same time flattened, and the total distance from glabella to lambda increased, the occiput being inclined backward. Therefore the occipital index of these crania is very large. The Koskimo crania are compressed on all sides, and therefore very long, the axis of the cranium being depressed.

I give here a series of measurements of crania, showing the typical deformations. I have to thank Professor F. W. Putnam, Director of the Peabody Museum of American Archæology of Cambridge, Mass., for his kind permission to me to describe the three Chinook crania.

—	Fig. 24.—CHINOOK. Wyman, 890. Male	Fig. 27.—CHINOOK. Peabody Museum, 38946. Male	Fig. 29.—CHINOOK. Peabody Museum, 6782. Child	Fig. 31.—Cox I. Male	Fig. 34.—May's Place. Female	Fig. 35.—Bull Harbour. Male?
	mm.	mm.	mm.	mm.	mm.	mm.
Horizontal length	166	170	155	160	181	199
Maximum length	167	171	155	161	181	199
Occipital length	—	37	55	39	55	73
Maximum width	157p	164p	152	160p	134p	137
Minimum frontal width	99	101	(90)	95	92·5	102
Height	125	129	—	134	131	130
Height of ear	116	116	—	120	115	114
Length of basis	(93)	106	—	95	99	106
Width of basis	(102)	113	94	(111)	99	105
Length of pars basilaris	25	28	—	26	25	27
Length of foramen magnum	35	38	—	38	39	35
Width of foramen magnum	28	32·5	—	29	30	29
Horizontal circumference	516	534	492	508	507	555
Sagittal circumference	334	334	305	335	357	399
Frontal arch of sagit. circum.	117	112	101	116	121	138
Parietal arch of sagit. circum.	105	114	104	119	109	133
Occipit. arch of sagit. circum.	112	108	100	100	127	128
Vertical circumference	315	330	—	330	298	296
Height of face	—	—	—	118	—	126
Height of upper part of face	70	78	52	70	69	80
Width of maxillary bone	96	107	72	105	91	110
Width between zyg. arches	140	148	108·5	149	125	141
Height of nose	50	55	36·5	50	49	60
Width of nose	22	27	19	23	22	23
Width of orbit	40	42	34	41	39	41
Height of orbit	36	38	32	36	36	41·5
Length of face	97	112	—	101	97	105
Length of palate	49	55	34	51	49	51
Anterior width of palate	39	44	30	39	37	34
Posterior width of palate	(45)	50	35	45	39	43
Capacity	1390cc.	—	—	—	—	—
Cephalic index	94·6	96·4	98·1	100·0	74·0	68·8
Index of height	74·7	75·9	—	80·4	72·4	65·3
Index of upper part of face	50·0	52·7	47·9	47·0	55·2	56·7
Index of nose	44·0	49·1	51·8	46·0	44·9	38·3
Occipital index	—	21·7	35·5	24·4	30·4	36·7

1. Wyman, 890. Adult male. Calvarium. The cranium is much flattened and asymmetrical, as appears in the norma occipitalis. Sutures open; teeth not worn. The sutures are rather complicated, a Wormian body in the right coronal suture, others in the left asterion. The sagittal suture from obelion to lambda is depressed, being the deepest line of a shallow groove. The left mastoid process is absent, two small elevations

FIG. 24.—Chinook Male.
(Wyman Collection, 890; Peabody Museum, Cambridge, Mass.)

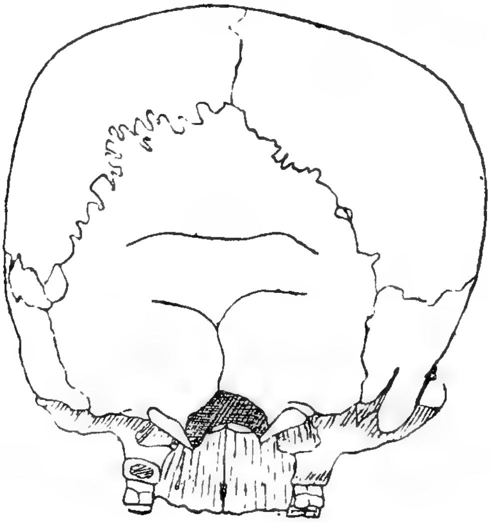


being the only indication. The condyles are small. The squama occipitalis is very asymmetrical, the occipital protuberance large but flat. The palate is high and arched; short traces of the sutura incisiva are found. The alveolar arch is almost angular at the canine teeth, turning suddenly backward. The right wisdom tooth is not developed. Fossa glenoidalis shallow; styloid processes large and heavy. Right ear round, left ear

FIG. 25.—Chinook Male. (Wyman Collection, 890.)

narrow, oval. Pars basilaris high. On the right side a complete processus frontalis of the temporal bone is found, and in addition to it an epipteric bone; on the left an incomplete processus frontalis and a larger epipteric bone are found. Part of the tissues of the face are preserved; upper portion of the face is coloured green by copper. The cross-section of the nose is high and rounded; its upper part is narrow, the lower rim rather sharp, the septum asymmetrical. The lacrymal ducts are small.

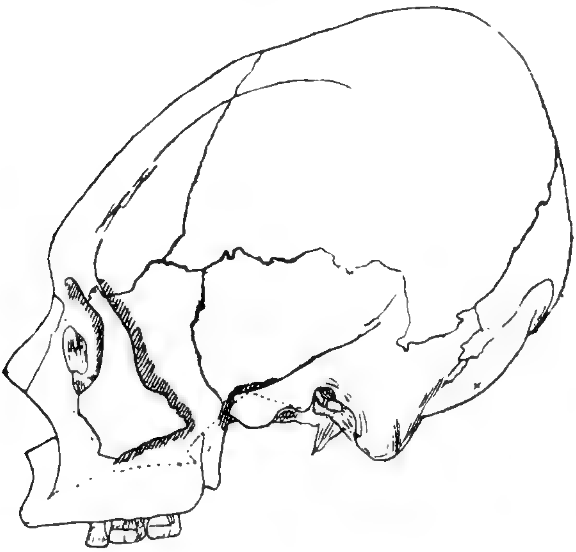
FIG. 26.—Chinook Male. (Wyman Collection.)



Superciliary ridges well developed; slight traces of frontal suture above nasion.

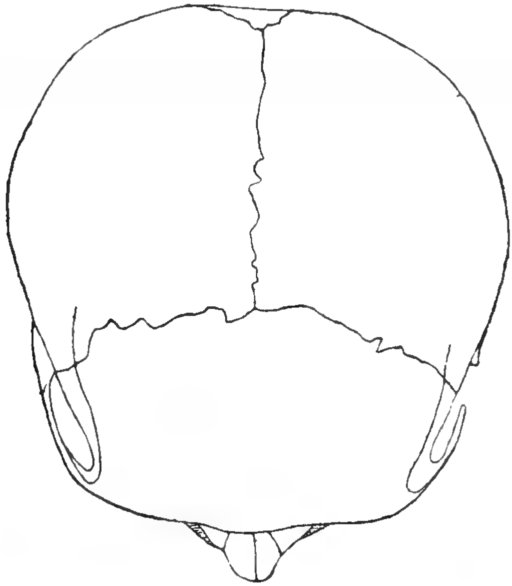
2. Peabody Museum, 38946. Adult male. Sutures open; teeth moderately worn. Left zygomatic bone broken. Calvarium. The skull

FIG. 27.—Chinook. (Peabody Museum, Cambridge, 38,946.)



is flattened in the same way as the foregoing. Sutures rather simple. A small Wormian bone in the lambda, others near both asteria. The superciliary ridges are strongly developed; the temporal lines short and indistinct. A trace of a double frontal suture extends from the nasion 1 cm. upward. The occiput is flat, the lineæ nuchæ very distinct. Mastoid processes large, incisuræ mastoideæ deep. The pars basilaris is wide, the condyles far apart, much curved. The styloid processes are large. The palate is high but flat-roofed. Teeth large; retention of

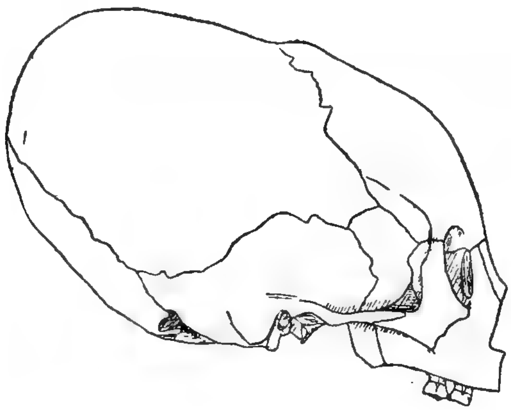
FIG. 28.—Chinook. (Peabody Museum, Cambridge, Mass., 38946.)



second left incisor. On both sides very large exostoses in ears. Alveolar arch rounded. Juga alveolaria large. Fossæ caninæ deep. Nose large. Nasal bones 30 mm. long, with many foramina. Cross-section of nose round. Prenasal fossæ. Septum asymmetrical. Edges of orbits overhanging.

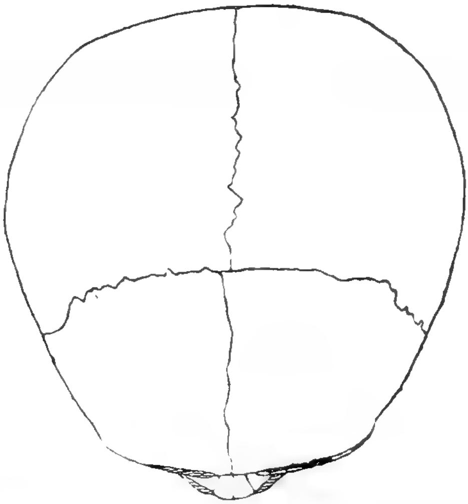
3. Peabody Museum, 6782. Child. Pars basilaris lost; right side of

FIG. 29.—Chinook. (Peabody Museum, Cambridge, Mass., No. 6782.)



occiput broken. Skull very much flattened; deep groove behind coronal suture. Sutures simple; frontal suture persistent. On inner side of frontal bone deep depressions of convolutions of brain. Squama occipitalis ellipsoidal. Palate very uneven. First and second molars developed, first dentition. Sutura incisiva open. Nose flat, lower edge rounded.

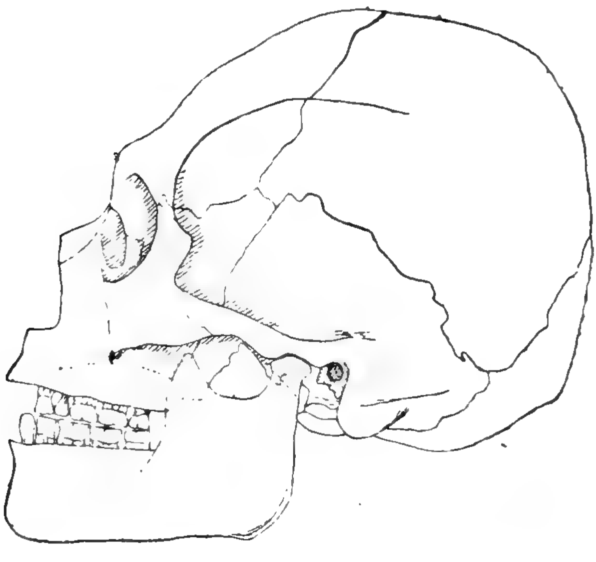
FIG. 30.—Chinook. (Peabody Museum, Cambridge, Mass., No. 6782.)



On the left side a small epipteric bone and a small frontal process of the temporal bone, which remains, however, 6 mm. distant from the frontal bone.

4. Cox Island. Adult male. Flattened from obelion to inion.

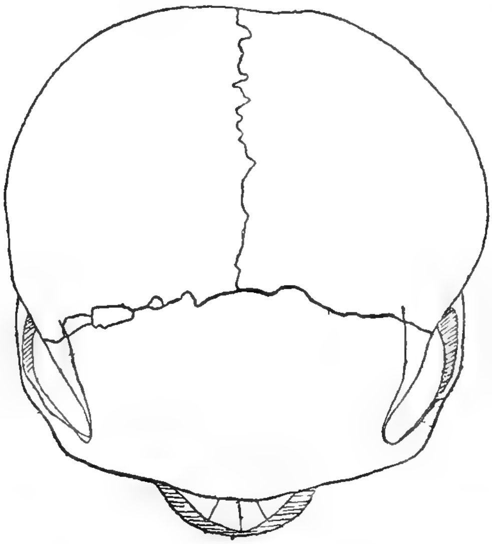
FIG. 31.—Cox Island.



Sutures open, simple. Wormian bones in right coronal suture. Forehead flat; superciliary ridges moderately developed. Pterion depressed.

Squama occipitalis low and flat. Incisuræ mastoideæ deep. Alveolar arch round; palate arched. Teeth moderately worn. Facial bones heavy. Root of nose flat, narrow. Lower rim of nose sharp. Lower

FIG. 32.—Cox Island.



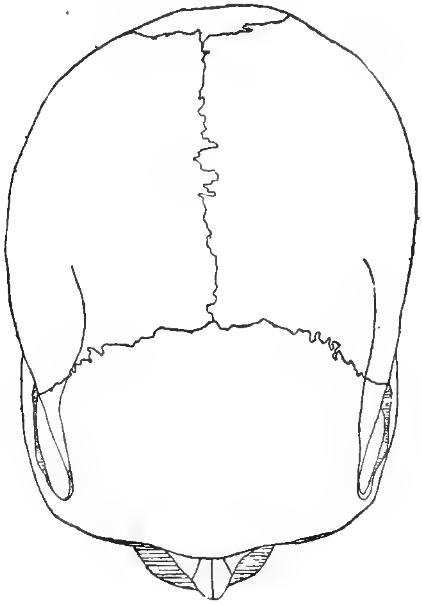
jaw heavy; incisura semicircularis small. Large epipteric bone on right side.

5. May's Place (Tliksiwi). Adult female. Sagittal and coronal sutures partly synostosed. Skull artificially lengthened. Sutures com-

FIG. 33.—May's Place.

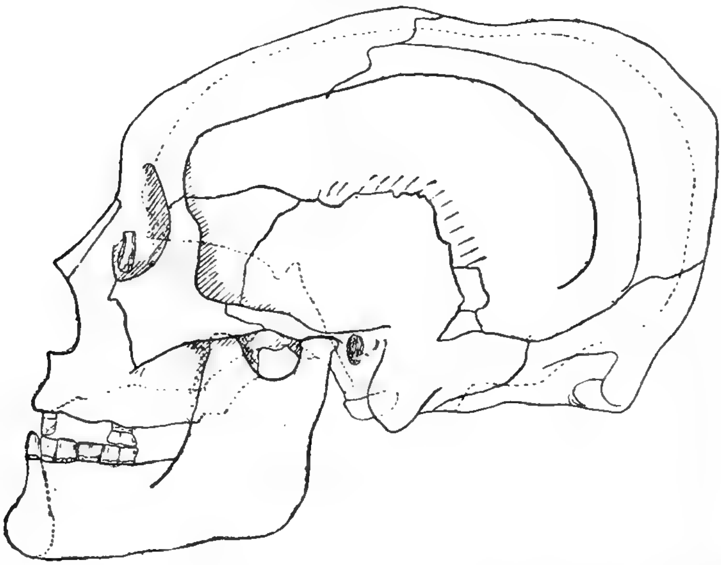
plicated. Squama occipitalis very high. Base of skull flat. Alveolar arch parabolical, narrow. Nose high; cross-section of nasal bones arched. Lower edge of nose sharp. Foramina infraorbitalia double. Slight trace of frontal suture near glabella. On right side large processus frontalis of temporal bone, separating the sphenoid from the parietal bone.

FIG. 34.—May's Place.



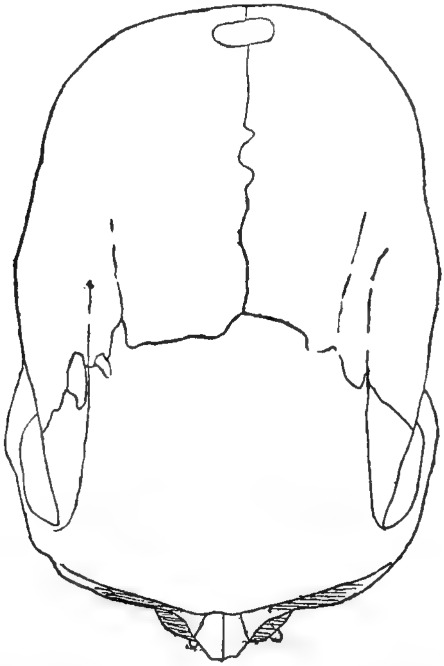
6. Bull Harbour. The cranium has all the characteristics of a male, although the excessive elongation is said to be practised on females only. The bones are thick, the whole cranium large and heavily built.

FIG. 35.



Sutures very simple, but a few Wormian bones are found in the right coronal suture. The teeth are well worn, the lower parts of the coronal suture synostosed. The frontal bone is long and narrow. Superciliary ridges large. Double temporal lines well developed. Depression all around the cranium behind the coronal suture. Exostosis at obelion.

FIG. 36.—Bull Harbour, No. 90.



Protuberantia occipitalis very large. Squama occipitalis narrow, high. Foramen magnum small; condyles small; mastoid process large. Incisura mastoidea of right side small. Nose very high and narrow; lower edge sharp. Orbits large.

It seems that the lateral compression of the cranium affects also the face, as the indices of the upper face and of the nose show.

LINGUISTICS.

KWAKIUTL.

In the following notes observations on the Hēiltsuk· and Kwakiutl dialects of this stock are contained. The former were obtained in the years 1888 and 1889 from a number of men who visited Victoria. The latter are derived from collections made at Hope Island and Alert Bay, 1886; Victoria, 1888; and Alert Bay, 1889. I give only such parts somewhat fuller in which my conclusions differ from those of the Rev. Alfred J. Hall, whose notes on the grammar of the Kwakiutl language were published in the 'Transactions of the Royal Society of Canada,' 1888, sec. ii. K. in the following chapter means Kwakiutl dialect; H. means Hē'iltsuk· dialect.

PHONETICS.

Vowels: a, â, e, E, i, o, u.
Consonants: b, p; w; m; gy, kH; g, k; g·, k·; q, Q; y, H; d, t, n; s, ts; (c, tc); l; dl, tl; h.

There is a strong tendency to elimination of vowels in the Hēiltsuk· dialect.

Tne surds and sonants are difficult to distinguish. *S* and *ts* have frequently a slight touch of the *c* and *tc*, the teeth being kept apart and the articulation being post-alveolar. I spell here *kH* in preference to *ky*, as this sound—the anterior linguo-palatal sound—is almost always strongly exploded. It is the sound described by Mr. Hall as 'the croaking of the raven.'

All sounds occur as initial sounds. There is a remarkable difference between the two dialects regarding initial combinations of consonants. Among approximately 1200 words of the Kwakiutl dialect I found the following beginning with more than one consonant:

k·qsis, trousers.	*qn*, my, but also *qEn*.
kH'qlak·, crow.	*tsk·uls*, obsidian (?).

In the Hēiltsuk· dialect the following combinations of consonants were found to begin words:

bg	ks	k·ks	kHk	Hm	qk	mky	sq	tk·	tlk
		k·kH	kHql		qt		ss		tlky
		k·p	kHp		qtl		sHs	tqk·	tlk·
								tqs	tlH
		k·s	kHsk·					tqtl	tlHs
		k·t						tHt	tlq
		k·ts						tsk·	tlqlk·
								tsq	
								tss	

It is of importance to note that these combinations occur rarely, and that they evidently originated through elimination of vowels. The following examples, taken from both the Hēiltsuk· and Kwakiutl dialects, will prove this fact:

	Hēiltsuk·.	Kwakiutl.
to speak (man),	*bqua'la* (=man's voice).	*bEgua'la* (*bā'kus*, men).
eye,	*k·ks.*	*k·a'yak·s.*
widower,	*k·kyâ'sit.*	*k·ekyâ'sit.*
bark,	*qk'um.*	*qa'k'um.*
grouse,	*mkyEls.*	*mā'koals.*
Chinook canoe,	*sqam.*	*sE'qem.*
to jump,	*tQuit.*	*tu'q'uit.*
bow,	*tlkuē's.*	*tlā'kuis.*
old woman,	*tlkoa'nē.*	*tlakoā'nē.*

All the combinations are such as are likely to originate through elimination of vowels. It is remarkable that the combination *ks*, *st*, *sp*, &c., do not occur.

Sonants do not occur as terminal sounds. *W* and *kH* do not terminate words. The following combinations are found to terminate words:

kk				mp	lks	qt
k·k	k·k·				k·s	k·Qt
qk					qs, pqs	
kHk						mt
lk	lk·	lq	mkH	mH	ls	nt
sk	nk·	nq	nkH		ms	st, qst
tsk	tsk·		qskH	msH	ns	
ntk	tk·	tq			ts, nts, lts	
	tlk·					

Grammatical Notes.

THE NOUN AND THE ADJECTIVE.

The noun has no plural, but a distributive, which is mostly formed by reduplication, epenthesis, or diæresis:

man, *bEguā'num*, K. H.	a deer, *k·ā'mēla*, H.
two men *mālū'k' bEguā num*, K.	a group of deer, *k·ak·ā'mēla*, H.
mālō'guis bEguā'num, H.	a stone, *t'ē'sEm*, K. H.
a group of men, *bēbEguā'num*, K. H.	a heap of stones, *t'ē't'asEm*, K. H.

When the noun is used as a verb corresponding to our noun with verbum substantivum the distributive may be used for forming the plural.

I am a smoker, *ua'qpisin*, K.	*uaqpisnō'gua*, H.
we (incl.) are smokers, *uī'uaqpisints*, K.	*uaau'qpisints*, H.
we (excl.) are Europeans.	*k'ōmHsī'oantk'* and *k'oē'k'ōmHsī'oantk'*, H.

The plural of adjectives with the verbum substantivum is formed in the same way.

dead, *tlEl*, pl. *tlē'tlEl*, K.	
sick, *ts'Eqk'a'*, pl. *tsē'ts'Eqk'a*, K.	*tlōqoa'la*, pl. *tlōtlōqoa'la*, H.

The plural of the verb is formed in the same way (see p. 663).

The genitive is expressed by the preposition *is*, which serves also to connect the adjective with the following noun:

Na'ntsē's child, *qōnō'k' is Na'ntsē*, H.
a large country, *k'ē'kyas is tsk'emsk'*, H.

NUMERALS.

Cardinal Numbers.

	K.	H.
1,	nEm.	mEn.
2,	mātl.	mātl.
3,	yūtq.	yūtq.
4,	mū.	mū.
5,	sky'a.	sky'a.
6,	k'atla'.	k'atla.
7,	atlibū'.	mātlaau's.
8,	mātlguanatl.	yu'tquaus.
9,	nā'nEma.	mā'mEnē.
10,	lastū.	ai'ky'as.
11,	nE'māyū.	mEnē,egyū.
12,	mā'tlagyū.	malā'gyū.
13,	yū'tqwāgyū.	yūtoā'gyū.
14,	mū'agyū.	mūa'gyū.
15,	sky'a'gyū.	sky'a'gyū.
16,	k'atla'gyū.	k'atla'gyū.
17,	atlibū'agyū.	mātlaau'sgyū.
18,	mātlguanatlagyū.	yutquau'sgyū.
19,	nā'nEmāgyū.	māmEnē'agyū.
20,	mātlsEmgyustāu.	māsE'mkōstēyō *or* māsEmkuistē'ua.
21,	nanEmk'âla.	mEnē'k'aōla.
22,	mā'tlaâla.	mātlaō'la.
23,	yūtqaâ'la.	yutqaō'la.
24,		mōk'oaō'la.
25,		sky'ak'aō'la.
30,	yūtqsEmgyustau.	yūtqsūk.
31,	yūtqsEmgyustau hīmisa nEm.	yūtqsuk gyigyi mEnū'k'.
40,		mōk'suk.
50,		sky'ā'ksuk.
60,		k'atlai'Hsuk.
70,		matsō'ukaus.
80,		yutqsūkaus.
90,		mā'mEnEHsū'koa.
100,	lā'kint *or* nEmpEnyā'gi.	ō'pEnHstais.
200,	mātl pEnyā'gi.	mātlpEnHstais.
1,000,	lō'qsEmH'īt.	lōqsEmH'īt.

It appears that in the Kwakiutl dialect eight and nine are formed from two and one respectively, being two and one less than ten. In the Hēiltsuk' dialect seven and eight are formed from two and three, as is the case in most languages of British Columbia. Nine is derived from one. The inversion of the consonants in the words for 'one' (*mEn* and *nEm*) is very curious.

The numerals take suffixes which denote the objects counted. Besides the class-suffixes for animate beings, round, long, flat objects, days, fathoms, the numerals may take any of the noun suffixes (see p. 665). The Rev. A. J. Hall has given a few classes in the Kwakiutl dialect on pp. 68 and 69 of his grammar. Here are a few classes taken from the Hēiltsuk· dialect:

—	One	Two	Three
Animate	*mEnō'k‘*	*māalō'k‘*	*yūtuk‘*
Round	*mE'nsk·am*	*mā'sEm*	*yūtqsEm*
Long	*mE'nts'ak·*	*mā'ts'ak·*	*yū'tuts'ak·*
Flat	*mEnaqsa'*	*mātlqsa*	*yūtqsa'*
Day	*ōp'ēnē'Quls*	*mātl p'ēnē'Quls*	*yutqp'ēnē'Quls*
Fathom	*ō'p'Enkh*	*mātlp'Enkh*	*yutqp'Enkh*
Grouped together	—	*mā'tlōutl*	*yū'tōutl*
Groups of objects	*nEmtsmō'ts'utl*	*mâtltsmō'ts'utl*	*yūtqtsmō'ts'utl*
Filled cup	*mEnqtlā'la*	*mātl'aqtlā'la*	*yūtqtlā'la*
Empty cup	*mEnqtla'*	*mā'tl'aqtla*	*yū'tqtla*
Full box	*mEnsk·amā'la*	*mā'sEmāla*	*yūtqsEmāla*
Empty box (see round)	*mE'nsk·am*	*mā'sEm*	*yūtqs'Em*
Loaded canoe	*mEnts'ak·ē'*	*mā'ts'ak·ē'*	*yūtuts'ak·ē'*
Canoe with crew	*mE'nts'ak·is*	*mā'ts'ak·la*	*yūtuts'ak·la*
Together on beach	—	*mā'alis*	—
Together in house &c.	—	*maa'lītl*	—

It appears from these examples that the number of classes is unlimited. They are simply compounds of numerals and the noun-suffixes.

Ordinal Numbers.

the first, *gyā'la*, H. at first, *gya'lH'it*, H.
the second, *ā'tl'it*, H.
the third, *wanā'ky'a*, H.
the last, *walā'qtlē*, H.

Numeral Adverbs.

once, *ō'pEnHit*, H. four times, *mōpE'nHit*.
twice, *mātlpE'nHit*, H. five times, *sky'apE'nHit*.
three times, *yūtqpE'nHit*, H. ten times, *hāitlōpE'nHit*.

PRONOUN.

Personal Pronoun.

The personal pronoun in the Kwakiutl dialect is very difficult to understand. There are two forms, but I cannot explain their separate use. It seems that only one form occurs in the Hēiltsuk· dialect:

	K.	K	H.
I,	*nō'gua, yin.*	me, *gyā'qEn.*	*nō'gua.*
thou,	*sō', yūtl.*	thee, *sōt.*	*k·qsō.*
he,	—		—
we (incl.),	*nō'guants, yints.*	us, *gyā'qEnts.*	*nōgua'nts.*
we (excl.),	*nō'guanuq, yi'nuq.*	us, *gyā'qEnuq.*	*nōgua'ntk‘.*
you,	*sōqdâ'q, yiQdaqō'tl.*		*k·aeksoā'ea.*

It is remarkable that while in Hēiltsuk· the plural of the second person is formed by reduplication, in the Kwakiutl dialect, the suffix *-dâq* is used for this purpose. We shall see later on that the same difference is found in the inflection of the verb. It seems that the stem of the second person is *sō*. I have not given the third persons, as they seem to be rather demonstrative pronouns.

In order to explain the use of the two separate forms in the Kwakiutl dialect I give a series of examples:

it is I, *nōguaEm.*

I, *nō'gua* (in answer to the question, Who is going to do it?)

I? *yin?* (in reply to, They say you stole it, also to the question, Who shall do it?)

I, *yin* (Shall he do it? No, I).

I will go, *nōquatl lātl.*
Is that thou? *sâ'o?*
thou, *sō'um* (in reply to: Who said so?)
we (will do it), *nō'guanuq.*
thou, *yūtl* (in answer to, Who shall do it? I? Yes, thou!)

Demonstrative Pronoun.

The Kwakiutl language distinguishes four locations of objects which take the place of demonstrative pronouns. The location is expressed by suffixes, which are used with all classes of words. They are the following:

	K.	H.
Near speaker,	*—ikʜ.*	*—ky.*
Near person addressed,	*—uq.*	*—uq.*
Distant, visible,	*—ē.*	*—a (ē).*
Distant, invisible,	*—ē'.*	*—ats (ēts).*

For instance:

	K.	H.
he (near speaker) is my father,	*kyē'mᴇn ō'mpikʜ.*	*nēsky au'mp.*
he (near person addressed) is my father,	*yū'mᴇn ō'mpuq.*	*nē'suq au'mp.*
he (absent, visible) is my father,	*hä'mᴇn ō'mpē.*	*nē'sē au'mp.*
he (absent, invisible) is my father,	*hä'mᴇn ō'mpē'.*	*nē'sēts au'mp.*

The following is the independent demonstrative pronoun in the Kwakiutl dialect:

he (near speaker), *gyat.*
he (near person addressed), *yūt.*
he (absent, visible and invisible), *hēt.*
they (near speaker), *gyâqdaoq.*
they (near person addressed), *yū'qdaoq.*
they (absent, visible and invisible), *hēqdaoq.*

Possessive Pronoun.

The adjective possessive pronoun is derived from the article-pronoun. In the Kwakiutl dialect it has a number of separate forms, formed by one of the letters *q*, *s*, *ts*, and the termination derived from the article-pronoun. It seems that *q* stands for the subject and object, *s* and *ts* for the genitive and instrumentals. It is, however, far from certain that this explanation is correct. The terminations are in the Kwakiutl dialect:

Singular, 1st person, *n.*
„ 2nd „ *—is.*
„ 3rd „ *—s.*

Plural, 1st person, inclusive, *nts.*
„ „ „ exclusive, *nuq.*
„ 2nd „ *—is daoq.*
„ 3rd „ *—daoqs.*

Generally the location of the object possessed, and in the third person also that of the possessor, is expressed by means of the demonstrative terminations. The latter is placed between the character of the pronoun (*q*, *s*, *ts*) and its termination, and is also affixed to the noun. The pronouns of the first person seem to take the demonstrative ending for 'near the speaker' only.

—	My father	Thy father	Our (inclusive) father	Our (exclusive) father	Your father
Near speaker	*qgyin ō'mpikʜ*	*qky â'siky*[1]	*qgyints ō'mpiky*	*qgyinuq ō'mpiky*	*qky â'sdaoqiky*
Near person addressed	*qᴇn ō'mpuq*	*quq â'suq*	*qᴇnts ō'mpuq*	*qᴇnuq ō'mpuq*	*quq âsdaoquq*
Absent, visible	*qᴇn ō'mpā*	*q â'sa*	*qᴇnts ō'mpa*	*qᴇnuq ō'mpa*	*q â'sdaoqa*
Absent, invisible	*qᴇn ō'mpē'*	*q â'sē*	*qᴇnts ō'mpē'*	*qᴇnts ō'mpē'*	*q â'sdaoqē'*

[1] *âs*, thy father; *ōmp* is a compound of the stem *â* (from *awa*) and *-ᴇmp* designating relationship. The latter evidently drops out in the second person.

His father				
—	Near speaker	Near person address'd	Absent, visible	Absent, invisible
Near speaker	*yiqkye ō'mpkyes*	*yiqkye ō'mpkyasuq*	*yiqkye ō'mpkyasē*	*yiqkye ō'mpkyasē'*
Near person addressed	*yiquq ō'mpuqsiky*	*yiquq ō'mpuqs*	*yiquq ō'mduqsē*	*yi'quq ō'mpuqsē'*
Absent, visible	*yiq ōmpasiky*	*yiq ōmpasuq*	*yiq ō'mpas*	*yiq o'mpasē'*
Absent, invisible	*yiq ō'mpēsiky*	*yiq ōmpēsuq*	*yiq ō'mpēsa*	*yiq ō'mpēsē'*

Their father is formed correspondingly: *yiqkye ōmpdaoqkyes*, &c.

The use of the various forms of the possessive pronoun is illustrated by the following examples:—

hēEm wā'tldEm qn ō'mpa, that is what they said to my father (literally, that the word to my father).
hē'Em wā'tldEm sEn ō'mpa, that is what my father said (that is my father's word).
hēEm wā'tldEmtl tsn ō'mpa, that is what my father will say.
hēEm wātldEmtl qn ō'mpa or *tsē qn ō'mpa*, that is what they will say to my father
gyū'koa sEn ō'mpa, my father's house.
qn ō'mpa aq'ē'tEk·, my father took it.
ts'â tsEn tltE'mtluq la qn ō'mpa, give my hat to my father.
ts'â qn tltE'mtluq, give to my hat!
t'ap'ē'tEntla qyiskyin likyā'yukH, I broke this with my hammer here.
t'ap 'ē'tEntla qgyin likyā'yukH, I broke my hammer here.
qn ō'mpa aq'ē't tsn tltE'mtla, my father took my hat (away).
qn ō'mpa aq'utltsōt {*tsn* / *qn*} *tltE'mtla*, my father took my hat (but left it here).

When the sentence contains an interrogative or demonstrative pronoun the possessive pronoun is generally attached to them.

wī'dEn likyā'yū? where is my hammer?
wī'nEn ō'mpa? where is my father?
gyi'mEn likyā'yū, here is my hammer.
gyea'mgyin ōmpky nē'kya, my father here said this.
hē'mEn ō'mpa nē'kya, my (absent) father said it.

The pronoun may be affixed to the noun as well:

he (absent) is thy father, *hä'Em ō'mpē* and *hä'Em â'sē*.
he (absent) is your father, *häEms ō'mpdaoquē* and *häEm â'sdaoquē*.

It is remarkable that the possessive suffix may be given to the verb as well, at least in imperative forms:

give me thy hat (near thee), *g·ē'tsōs tltE'mtluq*.

SUBSTANTIVE POSSESSIVE PRONOUN.

—	Mine	Thine	Ours (inclusive)	Ours (exclusive)	Yours
Near speaker	*nō'siky*	*hō'siky*	*nō'sEntsiky*	*nōsEnuqkH*	*hō'sdaoqky*
Near person addressed	*nō'suq*	*hō'suq*	*nō'sEntsuq*	*nō'sEnuquq*	*hō'sdaoquq*
Absent, visible	*nō'sē*	*hō'sē*	*nō'sEntsē*	*nō'sEnuqē*	*hō'sdaoqē*
Absent, invisible	*nō'sē'*	*hō'sē*	*nō'sEntsē'*	*nō'sEnuqē'*	*hō'sdaoqē'*

His				
—	Near speaker	Near person addressed	Absent, visible	Absent, invisible
Near speaker	*haskyā'k·ikH*	*haskyā'k·uq*	*haskyā'k·*	*haskyā'k·ē*
Near person addressed	*hasō'quqk·ikH*	*hasō'qoak·uq*	*hasō'qoak·*	*hasō'qoak·ē*
Absent, visible	*hasē'k·ikH*	*hasō'k·uq*	*hasē'k·*	*hasē'k·ē*
Absent, invisible	*hasē'k·ikH*	*hasōk·uq*	*hasē'Ek·*	*hasē'Ek·ē*

Theirs is formed in the same way: *hasdaoqkyā'k·ikн*, &c.
The possessive pronoun of the Hëiltsuk· dialect is far less complicated.

ADJECTIVE POSSESSIVE PRONOUN.

Singular, 1st person,	*k·s*—	Plural, 1st person	(incl.),	*k·ants*—	
„ 2nd „	—(*ō*)*s*	„ 1st „	(excl.),	*k·antk'*—	
„ 3rd „	—*s*	„ 2nd „		—(*ō*)*s*	noun redu-
		„ 3rd „		—*s*	plicated.

We have to distinguish in this dialect also the four locations of near to speaker, near person addressed, visible, invisible.

—	My father	Thy father	Our (inclusive) father	Our (exclusive) father	Your father
Near speaker .	*k·sau'mpkн*	*au'mpkys*	*k·antsau'mpkн*	*k·antkau'mpkн*	*aiau'mpkys*
Near person addressed	*k·sau'mpuq*	*au'mmpuqs*	*k·antsau'mpuq*	*k·antkau'mpuq*	*aiau'mpuqs*
Absent, visible	*k·sau'mpa*	*au'mpōs*	*k·antsau'mpa*	*k·antkau'mpa*	*aiau'mpōs*
Absent, invisible	*k·sau'mpats*	*au'mpatsōs*	*k·antsau'mpats*	*k·antkau'mpats*	*aiau'mpatsōs*

His father				
—	Near speaker	Near person addressed	Absent, visible	Absent, invisible
Near speaker	*au'mkyaskн*	*au'mpuqsky*	*au'mpaskн*	*au'mpatskн*
Near person addressed	*au'mkyasuq*	*au'mpuqsuq*	*au'mpasuq*	*au'mpatsuq*
Absent, visible	*au'mkyasē*	*au'mpuqsē*	*au'mpasē*	*au'mpatsē*
Absent, invisible	*au'mkyasīts*	*au'mpuqsīts*	*au'mpasīts*	*au'mpatsīts*

Their father is formed in the same way from the reduplicated noun: *aiau'm-kyaskн*.

SUBSTANTIVE POSSESSIVE PRONOUN.

—	Mine	Thine	Ours (inclusive)	Ours (exclusive)	Yours
Near speaker . .	*nē'sōkн*	*k·ausō'kн*	*nēsō'k·ᴇntskн*	*nēsō'k·ᴇntk'kн*	*k·ēk·ā'usōkн*
Near person addressed	*nē'sōq*	*k·ausō'q*	*nēsō'k·ᴇntsuq*	*nēsō'k·ᴇntkuq*	*k·ēk·ausō'q*
Absent, visible . .	*nē'sē*	*k·ausē'*	*nēsō'k·ᴇntsē*	*nēsō'k·ᴇntkē*	*k·ēk·ā'usē*
Absent, invisible .	*nē'sēts*	*k·ausē'ts*	*nēsō'k·ᴇntsēts*	*nēsō'k·ᴇntkēts*	*k·ēk·ā'usēts*

his (absent, visible), *asō'k·oē*.
„ („ , invisible), *asō'k·oēts*.

theirs (absent, visible) *aēsō'k·oē*.
„ („ , invisible), *aēsō'k·oēts*.

THE VERB.

INTRANSITIVE VERB.

Kwakiutl Dialect.

1. *Noun or Adjective with* verbum substantivum.

smoker, *ua'qpis*.

1st person singular,	*ua'qpisin*
2nd „ „	*ua'qpits.*
3rd „ „ near speaker,	*ua'qpisīkн.*

3rd	person	singular,	near person addressed,	*ua'qpisuq.*
3rd	„	„	absent, visible,	*ua'qpisē.*
3rd	„	„	absent, invisible,	*ua'qpisēE.*
1st	„	plural,	incl.,	*uī'uaqpisEnts.*
1st	„	„	excl.,	*uī'uaqpisEnuq.*
2nd	„	„		*uīua'qpits.*
3rd	„	„	near speaker,	*uīua'qpisīkH.*
3rd	„	„	near person addressed,	*uīua'qpisuq.*
3rd	„	„	absent, visible,	*uīua'qpisē.*
3rd	„	„	absent, invisible,	*uīua'qpisēE.*

2. *Intransitive Verb.*

to eat, *hamā'p.*

1st	person	singular,		*hamā'pEn.*
2nd	„	„		*hamā'pEs.*
3rd	„	„	near speaker,	*hamā'pikH.*
3rd	„	„	near person addressed,	*hamā'puq.*
3rd	„	„	absent, visible,	*hamā'pē*
3rd	„	„	absent, invisible,	*hamā'pē'.*
1st	„	plural,	incl.,	*hamā'pEnts.*
1st	„	„	excl.,	*hamā'pEnuq.*
2nd	„	„		*hamā'pdaoqs.*
3rd	„	„	near speaker,	*hamā'pdaoq'ikH.*
3rd	„	„	near person addressed,	*hamā'pdaoq'uq.*
3rd	„	„	absent, visible,	*hamā'pdaoq'ē.*
3rd	„	„	absent, invisible,	*hamā'pdaoq'ēE.*

Hēiltsuk· Dialect.

1. *Noun or Adjective with* verbum substantivum.

smoker, *ua'qpis.*

1st	person	singular,		*ua'qpisnōgua.*
2nd	„	„		*ua'qpitsō.*
3rd	„ [1]	„	absent, visible,	*ua'qpitsē.*
1st	„	plural,	incl.	*uaau'qpisEnts.*
1st	„	„	excl.	*uaau'qpisEntk'.*
2nd	„	„		*uaau'qpitsō.*
3rd	„	„	absent, visible,	*uaau'qpisē.*

2. *Intransitive Verb.*

to drink, *nā'k·a.*

1st person sing., *nā'k·anōgua.*			1st person plural,	incl.,		*nāk·a'nts.*
			1st „	„	excl.,	*nāk·a'ntk'.*
2nd „	„	*nāk·a'sō.*	2nd „	„		*ak·ā'stla* and *nēnā'k·asō.*
3rd [1] „	„	*nāk·ā'sē.*	3rd [1] „	„		*nāk·ā'sē* and *nēnā'k·asē.*

I do not enter into the tenses of the verb, as the material at my disposal is not sufficient to bring out clearly the nice distinctions between the numerous tenses (see Hall, *l.c.* p. 79 ff.). I turn at once to the transitive verb with incorporated object, which has been treated very fragmentarily by Mr. Hall.

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[1] As the various forms of the third person are formed in the same way as those of the possessive pronouns, &c., they have been omitted here.

Kwakiutl Dialect.

to kill, *tlElā'mas.*

Object	Singular		
	1st person	2nd person	3rd pers. near speaker
1st pers. sing.	—	*—as gyā'qEn*	*—ikH*[1] *gyā'qEn*
2nd „ „	*—Entlutl*	—	*—ikHutl*[3]
3rd „ „[1]	*—Entlak·ikH*	*—asē'k·ikH*	*—kyā'k·ikH*[4]
1st pers. plur. incl.	—	—	*—īkH gyā'qEnts*
1st „ „ excl.	—	*—as gyā'qEnuq*	*—īkH gyā'qenuq*
2nd „ „	*—daoqEntlutl*	—	*—daoqikyutl*
3rd „ „[1]	*—daoqEntlak·īkH*	*—daoqasē'k·ikH*[2]	*—daoqkyā'k·īkH*

Object	Plural			
	1st pers. incl.	1st person excl.	2nd person	3rd person
1st pers. sing.	—	—	*—daoqas gyā'qEn*	*—daoqikH*[1] *gyā'qEn*
2nd „ „	—	*—Enuqūtl*	—	*—daoqikyūtl*[3]
3rd „ „[1]	*—Entsak·īkH*	*—Enuquak·īkH*	*—daoqasēk·īkH*	*—daoqkyā'k·īkH*[4]
1st „ plur. incl.	—	—	—	*tlētlElāmasdaoqikH gyā'qEnts*[8]
1st pers. plur. excl.	—	—	*—daoqas gyā'qEnuq*[6]	*tlētlElāmasdaoqikH gyā'qEnuq*
2nd pers. „	—	[5] —	—	*tlētlElāmas daoqikyūtl*
3rd „ „[1]	[5] —	[5] —	*—daoqasEk·īkH*[7]	*tlētlElāmas-daoqkyā'k·īkH*[4]

The characters of the tenses: *—utl* for the past and *—tl* for the future follow the stem of the verb:

we are going to kill thee, *tlElāmastlEnu'qūtl.*
we have killed thee, *tlelāmas'utlEnu'qūtl.*

The transitive verb may be inflected by means of auxiliary verbs, in which case the latter are treated like an intransitive verb, while the verbal stem retains the incorporated pronoun or is followed by the pronominal object.

I have killed thee, *LEmEn tlElā'masūtl.*
I have killed him (near me), *LEmEn tlElā'mask·īkH.*
thou hast killed me, *LEE'ms tlElā'mas gyā'qEn.*

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[1] The form for 'person near speaker' is here given; for 'near addressed person' the ending is *—uq* instead of *—ikH*; for absent, visible, *—ē*; for absent, invisible, *—ēE* or *ē'*.

[2] Also instead of the plural form with *—daoq* with reduplication: *tlētlElā masase'k·ikH.*

[3] Near person addressed: *—uqūtl*; absent, *—ēūtl.*

[4] The various forms corresponding to the locations of subject and object correspond to those of the substantive possessive pronoun, third person (see p. 660).

[5] These forms have the same ending as that with the object in 3rd (viz. 2nd) person singular, but is reduplicated: *tlētlElāmasEntsak·ī'kH, tlētlElā'masEnuqūtl,* and *tlētlElā'masEnuqūak·ī'kH.*

[6] Or *tlētlElā'masas gyā'qEnuq.*

[7] Or, if it does not appear from the context that the object is plural: *tlētlElāmasasēk·ī'kH.* The forms of the subject, second person singular, object, third person plural, and subject, second person plural, object, third person singular and plural are identical; it must be decided from the context what is meant.

[8] In this and the following form the verb *must* be reduplicated.

Hēiltsuk· Dialect.

to kill, *ᴇlqa* (— stands for the singular, *ᴇlqa* : = for the plural, *aiᴇlqa*).

Object	Singular		
	1st person	2nd person	3rd person [2]
1st person singular	—	—*sōntla*	—*kyintla*
2nd „ „	—*nōgutla*	—	—*kyūtla*
3rd „ „ [1]	—*nō'guak·kʜ* [1]	—*sōk·kʜ*	?
1st „ plural incl.	—	—	—*kyintlints*
1st „ „ excl.	—	=*sōntlintk'*	—*kyintlintk'*
2nd „ „	=*nō'gutla*	—	=*stlsōsk·kʜ* [3]
3rd „ „ [1]	=*nōguak·kʜ*	=*sōk·kʜ*	?

Object	Plural			
	1st person incl.	1st person excl.	2nd person	3rd person [2]
1st person sing.	—	—	=*sōntla*	=*kyintla*
2nd „ „	—	—*mᴇntkutla*	—	=*kyūtla*
3rd „ „ [1]	—*mᴇntsk·kʜ*	—*mᴇntkkʜ*	=*sōk·kʜ*	?
1st „ plur. incl.	—	—	—	=*kyintlints*
1st „ „ excl.	—	—	=*sōntlintk'*	=*kyintlintk'*
2nd „ „	—	=*mᴇntkutla*	—	?
3rd „ „ [1]	=*mᴇntsk·kʜ*	=*mᴇntkkʜ*	=*sōk·kʜ*	?

The characters of the tenses —*aiʜte* for the past and —*tl* for the future follow the stem of the verb.

The principal differences between the inflexions of the transitive verbs in the two dialects are found in the incorporation of the object first person in the verb in the Hēiltsuk· dialect and the constant reduplication of the stem in the same dialect. The latter evidently disappeared in the Kwakiutl dialect through the use of the plural —*daoq*. Auxiliary verbs are used in the Hēiltsuk· in the same way as in the Kwakiutl.

Imperative.

	Kwakiutl.	*Hēiltsuk·.*
eat ! (singular)	*hāma'p !*	*ha'msᴇʜs !* [5]
let us eat !	*hamh'ī'tatsᴇnts !* [4]	*haia'msᴇʜsᴇnts !*
eat ! (plural)	*hē'map !*	*haia'msᴇʜs !*

Hēiltsuk· :	let him (near speaker) eat !	*hamsᴇʜsē'k·kh !*
	let him (near speaker, food near speaker) eat !	*hamsᴇhsē'k·kʜ !*
	let him (food, absent, visible) eat !	*hamsᴇʜsē k·ēk· !*
	let him (absent, visible) eat !	*hamsᴇʜsē'lē !*
	let him (absent, invisible) eat !	*hamsᴇʜsēlē'ts !*

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[1] The third person location near speaker is given. The other forms are formed from the corresponding endings : near person addressed, —*nōguak·uq* ; absent, visible, —*nōguak·ē* ; absent, invisible, —*nōguak·ēts.*

[2] Near person addressed, —*uqintla* ; absent, visible, —*ēintla* ; absent, invisible, —*ētsintla.*

[3] Also = *kyūtla.* *aiᴇlqastlsō'sē* he (absent, visible) will kill you. This form appears rather doubtful.

[4] Formed from another derivative of the stem *ham*, to eat, viz., *hamʜ'it* ; while the others are derived from *hāma'p.*

[5] From *ha'msa.*

	Kwakiutl		Heiltsuk·	
	Strike (singular)	Strike (plural)	Kill (singular)	Kill (plural)
me!	*miH'ī'tas gyā'qEn*	*miH'ītiHda'oqelas gyā'qEn*	*Elqahsen'tla*	*aiElqaHSE'ntla*
him! (near speaker)	*miH ī'task ikH*	*miH'ītiHda'oqelas·k·ikH* &c.	*Elqahsē'k·ikH*	*aiElqaHsē'k·ikH*
us!	*miH'ī'tas gyā'qEnuq*	—	*ElqaHSE'ntlintk'*	*aiElqaHSE'ntlintk'*
them!	same as singular	—	*aiElqaHsē'k ikH*	*aiElqaHsē'k ikH*

let me feed thee! *hamgyīlalasEntlūtl*, K.
let me feed you! *hamgyīladaoqlasEntlūtl*, K.
let us feed thee! *hamgyīlalā'sEnōqūtl*, K.
let us strike him, them! *miH'ītasEntsak·*, K.

let us kill him! *ElqaHSE'ntsk·ē*, H.
let us kill them! *aiElqaHSE'ntsk·ē*, H.

An interrogative exists in both dialects, but it has not become quite clear to me:

dost thou eat? *hamsa'sa?* H.
does he (near pers. addr.) eat? *hamsa'euqtsa?* H.
do you eat? *haia'msEs?* H.

One of the most important characteristics of the verb is that, whenever it is accompanied by an adverb, the latter is inflected, not the verb:

I do not eat, *kyēō'snōgua ha'msa*, H.
he did not(1) say(2) so, *kyē'sīkH*(1) *nē'kya*(2), K.

In the case of transitive verbs the adverb takes the ending corresponding to the intransitive verb, the verb retains the incorporated object. Thus the adverb assumes the character of an auxiliary verb. In some cases the object is treated in the same way:

we see (2) all (1) of them, *āgya'mEntk'* (1) *dōk·ola'k·aē* (2), H.

FORMATION OF WORDS.

Mr. Hall does not enter into this subject very fully, and the following notes will, for this reason, be welcome. The analysis of words of the Kwakiutl language is very easy. A great number of nouns occur in two separate forms, independent and dependent. Whenever such a noun occurs in connection with another word it is incorporated in the latter. So far as I am aware, only suffixes occur in Kwakiutl. A number of these nouns signify classes, for instance tree, female. Locative suffixes are found in very great numbers. Adjectives and verbs are also incorporated. I give a list, arranged alphabetically:

about, here and there	—*uilila*,[1] K.	*tlē'kuilila*, moving about. *lâ'kuilila*, camping here and there.
along	—*ntala*, K.	along round object: composed with —*nūts*, side of—, *k·ā'tsnūtsEntāla*, to walk along round object. along flat object: composed with —*Enq*, edge of—, *k·ā'tsEnqEntāla*, to walk along flat object.
always	—*tl*, K.	*amā'qulatl*, always giving away blankets. *baqbaku'latl*, always eating human flesh.
among	—*ak·a*, K. H.	*nEq'ak·ā'la*, to pull out of full box, K. (*i.e.*, from among). *mā'k·ak·a*, to throw among, H.
arm, upper	—*sīāpē*, K. H.	*ōqsīāpē'*, upper arm, K. H. *tl'ētsīāpē'*, skin of upper arm, K. *k'uk·utsīā'pē*, skin of upper arms, H.

[1] The —*la* in this and several others is probably a verbal suffix.

around	*—ēsta*, K. H.	*k·ā'tsēstala*, to walk all around, K.
		tōē'stala, to go all around, H.
		ōwē'sta, rim.
back	*—īkya*, K. H.	*awī'kya*, back, K.
		ōsk·amē'kya, back, H. (=round outside of back)
		miHī'kyent, K., to strike back.
beach	*—is*, K. H.	*lē'qois*, wide beach, K.
		ya'k·ōis, driftwood on beach, H.
	—lis, K. H.	*ēigyispalis*, sandspit on beach, K. (*aikH*, good, *—is* beach [compound *ēigyis*=sand], *—pa* point, *—lis* beach). Cf. country.
body	*—na*, H.	*ōkona'*, body, H.
		tlōqoana'la, sick all over body, H.
bottom of	*—qstē*, K.	*o'qstē*, bottom of a thing, K.
	—qtē, H.	*k·qa'qte*, notch of arrow (=notch in bottom), H.
breast	*—poē*, K.	*ōpo'ē*, breast, K.
		hā'k·'ōpoē, breastbone, K.
	—poa, H.	*ts'iō'poa*, breastbone, H.
to call	*—qa*, K.	*Quā'qunaqan*, I call a canoe's name, *i.e.*, want to buy a canoe.
in canoe	*—qsa*, K.	*gua'qsala*, to sit down in canoe (*gua*, to sit; *—qsa*, canoe; *—la*, verb).
	—qs, H.	*laqsut*, to load canoe (*la*, to go; *—qs*, in canoe; *—ut*, v.a.).
capable of	*—ts'Es*, K.	*dō'qts'Es*, seer (*dōq*—to see).
	—tEs, H.	*k·ā'wat'Es*, with good power of hearing.
to take care of	*—qsila*, K.	*mā'muqsila*, taking care of salmon weirs.
corner	*—nē*, K.	*gua'nē*, to sit down in corner.
country, outside house	*—us*, *—is*, K. H.	*bEg'u's*, man in woods, in country, K.
		tlāau's, to stand outside, H.
		wī'nakuis, world, K.
	—lis, K.	*hēstalis*, round the world (*—ēsta*, around; *lis*, country), K.
	—ālis, H.	*iuā'lis*, land where always wind, H. Cf. beach.
down	*—qa*, K. H.	*lā'qa*, to go down, H.
		k·ā'tsēqala, to go down, K.
down river	*—tusEla*, K. H.	*latu'sela*, to go down river in canoe, K.
ear	*—atoē*, K.	*ts'enā'tola*, ear is sick, K.
	—atoa, H.	*waksōdEtoa'*, both ears, H.
earth	*—gyilis*, K. H.	*lā'gyilis*, to land, K. H. (*la*, to go).
edge	*—nqē*, K. H.	*amai'nqē*, youngest child, K. (*ama*, small; *—nqē*, edge=smallest).
		māk·a'nqaut, to throw along, H. (*māk·a*, to throw; *—nqē*, edge; *—ut*, v.a.).
expert	*—pis*, K. H.	*nā'k·pis*, drunkard, K. H.
—	*—ilk·*, K. H.	*nā'k·ilk·*, drunkard, K. H.
		nāk·i'lk·in, I drink often, K.
eye	*—qstoē*, K.	*ēikHsōqstoē*, with pretty eyes, K.
	—qstoa, H.	*hā'baqstoa*, eyelashes, H. (*hāp*— hair).
face	*—Emaē*, K.	*mē'maatlEmaē*, two faces, K.
	—Emē, H.	*k'u'smē*, skin of face, H.
to do something with face	*—k·Em*, *sEm*, K. H.	*ā'ikyak·EmH'it*, to look up, K. (*āikya*, above; *—k·Em*, face; *—u'īt*, verb suffix), see: outside of round thing.
farthest	*—k·aua*, K.	*āikyak·aua*, farthest above, K.
fire	*—qtlala*, K. H.	*hā'nQtlala*, kettle on fire, K. H.
		k·'ēqtlala, much fire, K.
foot	*—sītsē*, K. H.	*k·oā'k·oansītsē*, toes, H.
		ōqtlaksī'tsē, heel, K.
forehead	*—a'oē*, K.	*aikya'oē*, pretty (=good forehead), K.
	—ē'ioa, H.	*tlāk·ē'ioa*, headring of cedar-bark, H.
fragment	*—tsEs*, K.	*Quā'kunatsEs*, fragment of canoe.

to go to look for	—*aiala*, K.	*hā'natlaia'la*, to go to buy a gun.
group	—*qsEm*, K.	*gyē'qsEm*, a group of chiefs.
hand	—*tsāna*, K.	*k·Emqō'tltsāna*, left hand.
	—*skyana*, H.	*k'ōqskyana*, hand cut off.
head	—*k·ēa*, H.	*tl'ō'k·k·ēa*, bareheaded.
head covering	—*mtl*, K. H.	*yiqu'mtl*, mask (= dancing head covering).
hindpart	—*qtlēe*, K. H.	*ōoqtlē'e*, stern of canoe, K.
		wala'qtlēk·s, youngest daughter, H. (—*k·s*, fem.).
in	—*tsō, tsoa*, K. H.	*lā'tsoa*, to enter, H. (*la*, to go).
		ts'ēntsâla, headache, K. (= inside sick).
instrument	—*ayō*, K. H.	*sī'wayō*, paddle, K.
		qtā'yō, knife, H.
interior of house	—*ītl*, K. H.	*goa'ītl*, to sit in house, K. H.
interior of man	—*īs*, K. H.	*sē'ilis*, snake in man, K.
large	—*tsē*, K.	*gyōktsē*, large house, K.
	—*kyā'oē*, H.	*t'ē'sEmkyā'oē*, large stone, H. (see: real).
to make	—*gyila*, K.	*hā'mggila*, to feed.
	—*ila*, K. H.	*hā'iatlila*, to mend, K.
motion	—*nakula*, K. H.	*k·ē'inakula*, to go straight ahead, H.
mouth	—*aqstē*, K.	*hā'paqstē*, beard, K.
	—*qta'ē*, H.	*hāpqta'ē*, beard, H.
inside of mouth	—*ētlqā'oē*, K.	*wapētlqā'oē*, saliva (water inside mouth), K. (See neck.)
mouth of river	—*siwaē*, K.	*tliQsī'waē*, mouth of river with clover roots.
neck	—*qā'oē*, K.	*ōqā'oē*, K., neck.
	—*qā'oa*, H.	*tl'ak·qā'oa*, H., neckring of cedar-bark.
noise	—*kyala*, K. H.	*k'ōmHsīuakyala*, H., white man's language.
	—*ala*, K. H.	*bgua'la*, K. H., to speak (man) (= man's noise).
		k·kya'la, K. H., to speak (female) (= woman's noise).
nose	—*itlpa*, K. H.	*a'lk'itlpa*, H., to bleed from nose.
on (roof, chair)	—*latlE* (*la*), H.	*gua'latlEla*, to sit on chair.
on flat object	—*tsuē*, K.	*k·ā'tsEltsuē*, to walk on a plank.
	—*tsoa*, H.	*tō'tsoa*, to walk on a plank.
on a long object	—*kyena*, K. H.	*guā'kyena*, to sit on a long object.
opposite	—*kyūt*, K.	*nEqkyū'ta*, opposite a rocky place (—*a*, rock).
other side	—*sut*, K.	*k·oē'sut*, far away on other side.
out of—	—*ōtltsoa*, K. H.	*tQ'ōtltsoa*, H., to jump out of.
outside of house	—*aqsē*, H.	*gua'qsē*, H., to sit outside the house.
outside, in woods	—*ils*, K. H.	*d'api'ls*, K., to flood ground.
participle passive	—*sō*, K. H.	*hā'inakyalasō*, K., the hated one.
penis	—*sak·āo*, K.	*mōqsak·â'o*, K., with tied penis (a name occurring in a tradition).
people	—*ēnoq*, K. H.	*tlask·'ē'noq*, K., people of the ocean.
		mā'q'ēnoq, K., killer whale (= secretly pursuing people).
		ha'lq'ēnoq, H., killer whale (= murderer).
	—*itq*, H.	*K·ōk·āi'tq*, H., people of K·ō'k·a.
	—*ala*, K.	*Tla'tlasik·oa'la*, K., people of the ocean.
place of, house of	—*as*, K. H.	*gy'ō'lōtas*, K., porpoise place.
place where something is regularly done	—*tEms*, K.	*k·uī'lastEms*, K., feasting place.
place of, probably hollow receptacle	—*atsē*, K. H.	*mEkōa'tsē*, H., mortar.
point	—*pa*, K. H.	*ai'kHpa*, K., sharp = good pointed.
pole	—*pik·*, K. H.	*mo'qpik·*, K., heraldic column (= pole to which [blankets] are tied).
to pretend	—*būtla*, K.	*mē'qabūtla*, to pretend to sleep.
purpose	—*numa*, K.	*k'āk·otlā'numa*, to come to learn.
to reach	—*k·a*, K. H.	*lā'k·a*, K., to go past.
real	—*kyasō*, K.	*bEgua'numkyasō*, a real man.
refuse	—*mūt*, K.	*hā'mūt*, rest of food.
	—*āoa*, H.	*hāmasā'oa*, rest of food.

relationship	—*mp*, H. K.	*au'mp*, H., father.
side of round thing	—*nūtl*, K.	*ō'nutlEmē*, cheek = side of face.
small	—*pitu*, plur.	
	—*mEnē'q*, K.	*gyōkpitū*, pl. *gyōkmEnē q*, small house.
	—*ōē*, H.	*gūk'ōē*, small house.
smell	—*p'ala*, K. H.	*ua'qp'ala*, smell of smoke.
stone	—*a*, K. H.	*gua'la*, H., to sit on stone.
superlative	—*k·amē*, K. H.	*nōlok·Emaē*, *nō'lok·amē*, K., the greatest fool.
surface of water	—*tlē*, K. H.	*gyilō'tlē*, to steal on water, to go stealing in canoe, K.
taste	—*p'a*, K. H.	*aikHp'a*, sweet = good taste.
through	—*qsī'oa*, H.	*laqsī'oa*, to go through—
time of—	—*Enq*, K. H.	*tlīE'nq*, H., time of potlatch.
tooth	—*Hē*, K.	*k·aqHē*, having lost one tooth (= notch in teeth).
	—*Hsia*, H.	*tlōqoaHsia*, toothache.
top	—*qto'ē*, K.	*gua'qtoa*, to sit on top of a thing.
top of box, bucket, &c.	—*kyaē*, K. H.	*wē'kyaē*, H., not quite full (*wē*, negation).
tree	—*mis*, K.	*bū'aqumis*, maple (= leaf tree).
under	—*a'poa*, K. H.	*tōū'put*, H., to walk under.
upward	—*ustâ* (*la*), K	*tl'Epustâ'la*, to climb a mountain.
	—*sustēwa*, H.	*d'ōqsustē'wa*, to look up.
verbal suffixes	—*Hit*, K. H.	*tl'ōpHit*, H., it is ebb tide.
	—*it*, K. H.	*nū'k·'it*, K., to drink.
	—*la*, K. H.	*tlōk·oa'la*, H., to be sick.
verbum activum	—*t*, K. H.	*tū'k·umt*, H., to cover face with blanket.
	—*ut*, K. H.	*la'qsūt*, H., to load canoe.
to want	—*ēqst*, K. H.	*nū'k·'ēqst*, K., thirsty.
water	—*sta*, K. H.	*tu'qsta*, H., to jump into water.
in water	—*is*, K. H.	*wīwunq'ā'pois*, H., bottom of sea (—*nqe*, edge; —*apoa*, under; —*is*, in water).
woman	—*k·a*, —*k·as*, K.	*tlōlē'k·as*, niece.
		ā'tak·a, pet daughter.
	—*aqsEm*, —*ks*, H.	*Bī'bilqulaqsEm*, Bilqula woman (stem reduplicated).
		mEnū'yak·s, sister.

NOOTKA.

The following notes have been derived from material collected in 1888 in Victoria from two Tlaō'kath, from other material collected 1889 in Alberni, principally from a half-blood Indian named Wa'tē. Bishop N. J. Lemmens, of Victoria, B.C., had the great kindness to give me the pronouns and the inflection of the verb in the Tlaō'kath dialect. A number of suffixes were obtained from a manuscript of the Rev. Father Brabant, who is said to be thoroughly conversant with the language. The dialect treated here is the Ts'iciā'ath, which differs somewhat from the northern dialects. Incidentally, remarks on the Tlaō'kath are given.

PHONETICS.

Vowels: a, e, E, i, o, ö, u.
Consonants: p; w; m; ky; k; k·, q; Q; y, H; t, n; s, ts (c, tc); tl; h.

s and *ts* partake of the character of *c* and *tc*, as in Kwakiutl, and it is doubtful whether they can be considered separate sounds. All consonants occur as initial sounds. No combinations of consonants occur in the beginning of words. The following terminal combinations were observed

		kh	k·s			
sk			hs		kt	k·tl
tck			qs		pt	qtl
tk	tk·	th	ms	mts	ct	mtl
						ntl

The terminal *m* and *n* are sonant and somewhat lengthened. In this dialect *h* takes generally the place of *q* of the northern dialects.

Grammatical Notes.

THE NOUN AND THE ADJECTIVE.

The noun has a singular and plural. The latter is formed by the suffix —*mᴇna*. In a few cases it is formed by reduplication, epenthesis, or diæresis.

fire, *i'nik*; pl. *ī't'inik* and *i'nikmᴇna*.
house, *mahtē*; pl. *mama'htē*.
village, *ma'utl*; pl. *ma'maūtl*.
common man, *mō'stcim*; pl. *maiā'stcima*.
child, *ta'na*; pl. *ta'tnēis* (—*is*, diminutive).
canoe, *tcā'pats*; pl. *tceyā'pats* and *tcāpatsmᴇna*.
man, *kōs*; pl. *kō'os*.
man, *tcᴇ'kup*; pl. *tcā'kupēa*.
island, *tcā'ok*; pl. *tcā'tcāk*.
woman, *tlō'tsma*; pl. *tlōtsama*.
chief, *tcā'mata*; pl. *tc'atcā'mata*.

I am not quite certain whether this is really a plural or whether it is rather a distributive. In a number of cases I found the singular form applied where we should expect the plural; *p.e.*, all the men, *tcōō'tc tcᴇ'kup*. My impression is that -*mᴇna* is a real plural, while the amplified stem is actually a distributive. The exceptions given above may be explained by assuming that the distributive is used instead of the plural. This opinion is supported by the fact that any noun when it is clearly distributive has a form corresponding to the exceptions given above. This becomes clear in compounds of parts of the body that are double. We find, for instance, in compounds with -*nuk*, hand:

bones of hands, *haha'mutnuku'm*;	from *ha'mūt*, bone.
flesh of hands, *ts'isk·tsēsnuku'm*;	„ *ts'i'sk·mis*, flesh.
second fingers, *tetē'itsnuku'm*;	„ *ta'ia*, elder brother.
skin of hand, *tutu'k·oak·nuku'm*;	„ *tu'k·oak·*, skin.
strong-handed, *na'cnāknuk*	„ *na'cuk*, strong.

The plural of adjectives with the verbum substantivum is formed in the same way:

sick, *tē'itl*;	pl. *tatē'itl*.
long, *iā'k·*;	„ *iā'iak·*.
large, *īh*;	„ *īī'h*.

(See p. 671, Inflection of the Verb.)

NUMERALS.

Cardinal Numbers.

1 nup. 1 *man*, ts'ō'wak.	9 ts'ō'wakutl.	100 sūtc'ē'k·.
2 ā'tla.	10 hai'ū.	120 nō'p'ōk·.
3 k·a'tstsa.	11 hai'ū ic ts'ō'wak.	140 a'tlpōk·.
4 mō.	20 tsa'k·ēits.	160 ā'tlakutlēk·.
5 sū'tca.	30 tsa'k·ēits ic hai'ū.	180 ts'ō'wakutlē'k·.
6 nō'pō.	40 atlē'k·.	200 hai'uk·.
7 a'tlpō.	60 k·atstsē'k·.	1000 sūtc'ēk·pᴇtūk·.
8 ā'tlakutl.	80 mōyē'k·.	

The system of numerals is quinary vigesimal. Eight and nine are respectively two and one less than ten.

The numerals take suffixes which denote the objects counted. Besides the class suffixes for round, long, flat objects, days, fathoms, the numerals may take any of the noun and verbal suffixes (see p. 676). The numerals are all derived from the same stems, the sole exception being one, *ts'ō'wak*, which is applied to men only. It is a curious fact that in counting objects other than men derivatives of *ts'ō'wak* are used for nine and twenty.

—	One	Two
round thing; animate	nu'pk·amitl	ā'tlak·amitl
long	nu'pts'ak·	ā'tlats'ak·
flat	—	—
day	nu'ptcitl	ā'tlatictl
fathom	nu'pietl	ā'tlietl
span	nu'pit	ā'tlpitanōutl
group of objects {	nu'ptak·ak·	—
	nupta'k·amitl	—
basket, bag	nuphtāk	ā'tlahtāk
round thing in canoe	nupk·a'mias	ātlak·a'mias
round thing on beach	nupk·a'miis	ātlak·a'miis
&c.		

Ordinal Numbers.

the first, ū'wi. *the second*, ō'pitcas. *the third*, o'hsnutl. *the last*, ōa'k·tlē.

Numeral Adverbs.

once, *nu'pit*. twice, *ā'tlpit*. three times, *k·a'tstsapit*.

Distributive Numbers.

one to each, *tsatsū'wak, nunu'p*.
two to each, *āā'tla*.
three to each, *k·aka'tstsa*.
four to each, *mō'mō*.
five to each, *susutc'a'*.
six to each, *nunupō*.

Distributive numerals are also formed from compound numerals:

one long thing to each, *nu'nuptsa'k·*.

THE PRONOUN.

Personal Pronoun.

		Kayokatq dialect.	
I, *sē'ya*.	me, *sē'tc'itl*.		
thou, *sō'ua*.	thee, *sō'titl*.		
he (*ots*).	—		
we, *nē'wa*.	us, *nē'hāitl*.	we, *nō'wa*.	us, *nō'haitl*.
you, *sī'wa*.	to you, *sē'haitl*.		
they (*ots*).			

In a few cases I find another personal pronoun derived from the article pronoun (see the Verb, p. 671):

we, *a'nine*. you, *anē'tsō*. they, *anē'atl*.
Tc'etc'im'i'sim'a anē'tsō mātemā'sis, make yourselves ready, you tribes.

Possessive Pronoun.

it is mine, *sēiā'sa*.
it is thine, *sōuā'sēits*.
it is his, *ō'tsmā*.
it is ours, *nēwā'sEn*.
it is yours, *sēwasē'itsō*.
it is theirs, *ōtsmā'atl*.

my, *-is*. our, *-k·ine*. his, *-yē*. their, *-yēetl*.
thy, *-ē*. your, *-itk·sō*. his (absent), *-ī*. their (absent), *-īētl*.

In terms of relationship the suffix *-ēk·sō*, forming the term, is omitted in the first and second persons of the possessive pronoun:

father, *nōwē'k·sō*.
my father, *nō wīs*.
thy father, *nō'wē*.
his father, *nōwē'k·sōyē*.

Demonstrative Pronoun.

this, *hitl'iē*; (*hē'is*, Tlaōkath).
that, *a'qha*; (*yū'is*, „).

The stem *hit-* is composed with suffixes denoting locality to form demonstrative pronouns, which are very numerous:

hitapois, that one underneath on beach.
hitahs, that one in canoe.
hititl, that one in house. &c.

THE VERB.

INDICATIVE.

—	Present	Imperfect	Perfect
1st person singular	*ha-u'kwah*	*ha-ukitah*	*ha-ukE'tlah*
2nd " "	*ha-ukoē'its*	*ha-ukitēits*	*ha-ukEtlē'its*
3rd " "	*ha-u'kma*	*ha-ukitma*	
1st " plural	*ha-ukwi'ne*	*ha-ukiti'ne*	&c.
2nd " "	*ha-ukoē'itsō*	*ha-ukitē'itsō*	
3rd " "	*ha-u'kmātl*	*ha-ukitātl*	

—	Plusquam Perfectum	Future	Futurum Exactum
1st person singular	*ha-ukEtlitah*	*ha-uka'k·tlah*	*ha-uka'k·tlitah*
2nd " "			
3rd " "			
1st " plural	&c.	&c.	&c.
2nd " "			
3rd " "			

There are four principal tenses, from which the others are derived: Present, Imperfect, Perfect, Future. The first is derived from the stem; the second has the character *-it*; the third, *-Etl*; the fourth, *ak·tl*.

In the plural forms the stem of the verb may be amplified by reduplication diæresis, or epenthesis, as the case may be.

Present.

1st person plural, *hāukwine* and *hāwakamine*.
2nd " " *ha-ukoē'itsō* " *hāwakamē'itsō*.
3rd " " *ha-u'kmātl* " *hawa'kamaatl* and *hawā'kama*.

Or, from *tē'itl*, sick:

1st person plural, *tē'itline* and *tatēitli'ne*

Other plurals of verbs are:

not to know, *hayi'mhe*; pl. *hā'hayımhe*.
to sleep, *wa'-itc*; " *hō itc*.
awake, *tlu'pka*; " *tlō'yupka*.
to sneeze, *tō'p'itscitl*; " *tōtōp'itscitl*.

When the stem of the verb ends with a vowel, *m* is inserted between stem and ending. It may also be used after the character of the perfect *-Etl*.

not to see, *tcā'tnē*. we eat, *hāwakami'ne*.
I do not see, *tca'tnēmāh*. I have eaten, *ha-ukE'tlah* and *ha-ukE'tlmah*.

When the stem of the verb ends in *p* the latter is transformed into *m* when followed by a vowel, except in the case of the perfect:

to know, *kā'mētap*. I know, *kāmētamā'h*. I have known, *kāmētapEtlā'h*.

The perfect is used frequently where we should expect the present tense. The imperfect is used in describing past events. The meaning of the other tenses needs no explanation.

CONDITIONAL.

The following forms were obtained from the Rev. Father Nicolai, the missionary stationed at Alberni:

	I should know.	I should have known.	I should have known, or I intended to know.
1st person singular:	*kāmētapō'sah.*	*kāmētapahitah.*	*kāmētapaqatlī'tah.*
2nd ,, ,,	*kāmētapōsē'its.*	&c.	&c.
3rd ,, ,,	*kāmētapōsma,* or *kāmētapōsa.*		
1st ,, plural	*kāmētapōsine.* &c.		

I have obtained none of these forms, but another instead; the form was obtained in the following sentence:

if I had been well I should have left, *wēkcahā'mitk·ōs wahā'kitlitk·ē s* (*wahā'k,* to leave).

By varying this sentence I obtained the following forms:

I should have gone, *wahā'kitlitk·ēs.*
thou wouldst have gone, *wahā'kitlitsuk.*
he would have gone, *wahā'kitlitka.*
we should have gone, *wahā'kitlitkine.*
you would have gone, *wahā'kitlitasuk.*
they would have gone, *wahākitlkaatl.*

The terminations of this form resemble those of the conditional in the Tlaō'kath dialect, which will be found further below.

SUPPOSITIONAL.

to kill, *k·a'qsap.*
if I should kill. &c.

—	Present	Past	Future	Futurum Exactum
1st pers. sing.	*k·aqsapk·ō's*	*k·aqsamitk·ō's*	*k·aqsapak·tlk·ō's*	*k·aqsapak·tlitk·ō's*
2nd ,, ,,	*k·aqsapk·ō'k*			
3rd ,, ,,	*k·aqsapk·ō'*			
1st ,, plur.	*k·aqsapk·u'ne*	&c.	&c.	&c.
2nd ,, ,,	*k·aqsapk·ō'sō*			
3rd ,, ,,	*k·aqsapk·ō'atl*			

The suppositional is also used as optative. It seems that in this case it takes a terminal *-c.*

I wish I could eat = if I could eat, *ha-u'kk·ōc.*
I wish thou couldst eat, *ha-u'kk·ōkc.* &c.

The same terminal *c* was found in a number of cases:

if he had been well I should have gone, *wēkcahā'mitk·ōc wohā kitlk·ēs.*

IMPERATIVE.

The imperative has a great variety of forms, and I was unable to classify them in any satisfactory way. According to Bishop Lemmens, the subjunctive and imperative are distinguished in the Tlaō'kath dialect, and similar forms may occur in the Ts'iciā'ath.

The most frequent forms are on *-ī* in the second person singular and *-itc* in the second person plural.

eat! (singular) *ha'-ukwi.*
eat! (plural) *ha'-ukwītc.*

drink! (singular) *nak·cii'.*
drink! (plural) *nak·ciitc.*

go away! *k·ē'itcē*; from *k ē'i.*

come here! *tcū kva.*

Relative.

The use of the relative form will become clear from the following example:

I say (1) so (2), who I am (3) shaman (4).
wamah (1) *tcō* (2) *yak·k·ās*(3)*ūcta'k·yū*(4).

1st person singular,	*yak·k·ās.*	1st person plural,	*yāk·k·ine.*
2nd „ „	*yak·k·ē'ik.*	2nd „ „	*yāk·k·ē'sō.*
3rd „ „	*yak·k·ē'i.*	3rd „ „	*yāk·k·ē'itatl.*

Past, *yak·itk·as.* Future, *yak·ak·tlk·as* or *yak·a'k·tlō.*

There are other variations of this form:

what a shaman (2) I am (1)! *k·oayē's* (1) *ūcta'k·yū* (2)!

which is inflected in the same way.

I believe the following form must be classed here also:

I know (1) that thou art (2) a shaman (3), *kama'tamah*(1)*anē'k* (2) *ūcta'k·yū.*

This form is inflected as follows:

1st person singular,	*anē's.*	1st person plural,	*ani'ne.*
2nd „ „	*anē'k.*	2nd „ „	*anē'sō.*
3rd „ „	*anē'.*	3rd „ „	*anē'tatl.*

The personal pronoun mentioned on p. 118 is evidently derived from the same stem.

Interrogative.

sick, *tē'itl*

1st person singular,	*tē'itlhas.*	1st person plural,	*tē'itlhenē.*
2nd „ „	*tē'itlhak.*	2nd „ „	*tē'itlhasō.*
3rd „ „	*tē'itlha.*	3rd „ „	*tē'itlhaatl.*

Passive.

to shake, *hi'scitl.*

Present.

1st person singular,	*hisciata'h.*	1st person plural,	*hisciati'ne.*
2nd „ „	*hisciatē'its.*	2nd „ „	*hisciatē'itsō.*
3rd „ „	*hi'sciatma.*	3rd „ „	*hisciatmaa'tl.*

Imperfect: *hiscianitah.*
Perfect: *hisciɛtlatah.*
Future: *hiscitlak·latah.*
Fut. exact.: *hiscitlak·tlanitah.*
Conditional: *hisciatosah* (according to Rev. Father Verbeck)
Subjunctive: *hisciatlis* („ „ „)

The Verb of the Tlaō'kath Dialect according to Bishop J. N. Lemmens.

Indicative.

to kill, *k·a'qsap.*

—	Present	Imperfect	Perfect
1st per. sing.	*k·aqsaps* or *k·aqsapsic*	*k·aqsamits* or *k·aqsapints*	*k·aqsapatls* or *k·aqsapatlsic*
2nd „ „	*k·aqsapitsk*	*k·aqsamititsk* or *k·aqsapintitsk*	
3rd „ „	*k·aqsapic*	*k·aqsapintic*	
1st „ plur.	*k·aqsapnic*	*k·aqsaminic*	
2nd „ „	*k·aqsapitsōc*	*k·aqsapintitsōc*	
3rd „ „	*k·aqsap(aka)ic*	*k·aqsapintic*	

—	2nd Perfect.	Plusquam perfectum	Future.	Futurum exactum
1st per. sing.	*k·aqsapāmits*	*k·aqsapatlints*	*k·aqsapak·tls*	*k·aqsapak·tlints* &c.
2nd „ „	*k·aqsapā'mititsk*	*k·aqsapatlintitsk*	*k·aqsapak·tlitsk*	
3rd „ „	*k·aqsapāmitic*	*k·aqsapatlintic*	*k·aqsapak·tlic*	
1st „ plur.	*k·aqssapā'minic*	*k·aqsapatlminic*	*k·aqsap·ak·tlnic*	
2nd „ „	*k·aqsapamititsōc*	*k·aqsapamititsōc*	*k·aqsapak·tlitsōc*	
3rd „ „	*k·aqsapāmitic*	*k·aqsapamitic*	*k·aqsapak·tlīc*	

CONDITIONAL.

1st Conditional

1st person singular, *k·aqsaptsimits*
2nd person singular, *k·aqsaptsimēitsk*
&c.

2nd Conditional

k·aqsapēqatlints or *k·aqsapē'qamits*
&c.

SUPPOSITIONAL

is identical with that of the Ts'iciā'ath dialect.

SUBJUNCTIVE.

let me kill, *k·aqsapā'qs*
thou mayest kill, *k·aqsapā'ets*
he may kill, *k·aqsapā'at*

let us kill, *k·aqsapā'ne*
you may kill, *k·aqsapā'atsō*
they may kill, *k·aqsapā'at*

IMPERATIVE.

2nd person singular, *k·a'qsape* or *k·aqsapetle'*
2nd person plural, *k·aqsapic* or *k·aqsapatlic*

RELATIVE.

—	Present	Past	Conditional
1st per. sing.	*yak·is*	*yak·emō'tis*	*yak·ōsis*
2nd „ „	*yak·ik*	*yak·emō'tik*	*yak·ōsik*
3rd „ „	*yak·ēi*	*yak·ēmō'tē* or *yak·emō'titk*	*yak·ō'sē* or *yak·ōsitek*
1st „ plur.	*yak·ine*	*yak·emō'tkine*	*yak·ōsine* or *yak·osecine*
2nd „ „	*yak·ēsō*	*yak·emō'titksō*	*yak·ōsēsō*
3rd „ „	*yak·ēi*	*yak·emō'tē*	*yak·ō'sē*

INTERROGATIVE.

dirty, *tsicgal.* *wāwa*, to say.

—	Present	Past	Past
1st person singular	*tsicgalhas*	*tsicgalinths*	*wawaimithas*
2nd „ „	*tsicgalk*	*tsicgalintk*	*wawaimitk*
3rd „ „	*tsicgalh*	*tsicgalinth*	&c.
1st „ plural	*tsicgalhine*	*tsicgalinthine*	
2nd „ „	*tsicgalhsō*	*tsicgalinthso*	
3rd „ „	*tsicgalh*	*tsicgalinth*	

PASSIVE.

to strike, *hiscitl.*

—	Present	Past	Future
1st person singular	*hisciats*	*hiscianits*	*hiscitlak·tlatsic*
2nd „ „	*hisciatitsk*	*hiscianititsk*	*hiscitlak·tlatēitsk*
3rd „ „	*hisciatic*	*hiscī'anitic* or *hisciatminic*	&c.
1st „ plural	*hisciatenic*	*hiscianitenic*	
2nd „ „	*hisciatitsōc*	*hiscianititsōc*	
3rd „ „	*hisciatic*	*hiscianitic*	

Futurum exactum : *hiscitlak·tlanits*
1st Conditional : *hiscitltsimatsic*
2nd Conditional : *hiscitlatahints*

SUBJUNCTIVE PASSIVE.

let me be struck (=strike me),	*hisciis*	let us be struck,	*hisciē'ne*
thou mayest be struck,	*hisciē'itsk*	you may be struck,	*hisciē'itsō*
he may be struck,	*hisciē'it*	they may be struck,	*hisciē'it*

INFINITIVE.

Active : to strike, *hiscitl* Passive : to be struck, *hisciat*

Participle.

one killing,	*k·aqsape'*	one being killed,	*k·aqsapati*
one having killed,	*k·aqsaptskme*	one about to kill,	*k·aqsapnahei*

Bishop Lemmens does not give any detailed information on the transitive verb incorporating the pronominal object. I found the following forms in the Ts'iciā'ath dialect. The terminations are suffixed to the verb with its various temporal characters. In order to simplify matters I give only the terminations:

Subject.

Object	Singular			Plural		
	1st Person	2nd Person	3rd Person	1st Person	2nd Person	3rd Person
1st person singular	—	—ē'itsEs	—ata	—	—ēitsō (?)	—atahatl
2nd „ „	—ah sō'titl	—	—atē'its	—ine sō'titl	—	—atē'itsatl
3rd „ „	—a	—ē'its	—atE'ma	—ine	—ē'itsō	—amaatl
1st „ plural	—	—ē'its nē'hetl	—atinE	—	—ē'itsō nē hetl	—atineatl
2nd „ „	—ah sē'haitl	—	—atē'etsō	—ine sē'haitl	—	—atē'etsōatl
3rd „ „	—ātl	—ē'itsatl	—atEmaa'tl	—ineatl	—ē'itsōatl	—atEmaatl

IMPERATIVE.

Subject.

Object	2nd person singular	2nd person plural
1st person, singular	—is	—itces
3rd „ „	—i	—itc
1st „ plural	—ine	—itcine
3rd „ „	—iatl	—itc'atl

NOTE.—Whenever the verb is accompanied by an adverb the latter may, and in the majority of cases does, take the verbal inflections.

I do not (1) sing (2), *wē'kah nonō'k.*

The looseness of the composition of the verb and its modal and temporal characters and personal terminations is clearly brought into view by this fact. The verb sometimes retains its temporal character, while the adverb takes both temporal character and personal ending.

If I had been well I should have gone, *ūyētlitah wēkcaha'mitk·ōs woha'k'atl.*
ūyētlitah, I should have been some time (from *ūyē*, some time).
wēkcaha', to be well. Suppositional past, 1st person singular, *wēkcaha'mitk·ōs.*
woha'k'atl, having gone, from *woha'k* to go, to leave.

DERIVATIVES.

Quotative : —*wo-i'n*, Tlaō'kath : *wa-i'c*
it is said he is sick, *tēitlwo-i'n* (Ts'iciā'ath)
tēitlwa-i'c (Tlaō'kath)

Desiderative:	—maaiqtl—	he wishes to eat, *ha-ukmaai'qtlma*
	—mēh—	I am thirsty, *nak·emē'ha*, from to drink, *nak·*—
Durative:	—ēik—	I eat always, *hawē'ikah*
Inchoative:	—utl—	I begin to sleep, *wäitcutlah*

Frequentative is formed by reduplication.

to yawn, *hacyēk·citl*, to yawn often, *hahā'cyik·a*

For others see under Formation of Words.

FORMATION OF WORDS.

The remarks made on the formation of words in Kwakiutl hold good in Nootka also. As the similarity of structure of the two languages is brought out very clearly in this respect I give a list for the purpose of comparison:

to acquire	—*ha*	*tlu'tcha*, marriage = buying a woman.
along, long	—*anutl*	*hinā'nutl*, along, up river.
		pītsā'nutl, cedar-bark rope.
among	—*ēksta*	*ōk·wē'ksta*, among certain people.
back	—*pē*	*a'ppē*, back.
		iā'kpē, sore back.
beach	—*is*	*k'a'nis*, to camp on beach.
		hitlasē'is, sandy beach.
belly	—*inak·ē*	*nacsink·ē'*, strong belly.
belonging to	—*iets*	*wēkiets*, orphan, belonging to nobody.
breast	—*asho(tl)*	*iā'kūshotl*, sore breast.
		tcā'upk·ashom, breastbone.
to cause, to make	—*ap*	*k·a'hsap*, to kill.
		ē'qsap, to make one cry.
out of canoe	—*ōtlta*	*tlōtcō'tlta*, landing a woman.
in canoe	—*ahs*	
dance	—*inek*	*titskatkinek*, thunder-bird dance.
daughter of	—*is*	*Tokwitis*, daughter of Tokwit.
down	—*atō*	*natc'ā'atō*, to look down.
dry	—*uct*	*tlossuct*, dry herring.
ear	—*imtl*	*iāiāa'mitl*, long-eared.
expert	—*nuk*	*kucnuk*, smoker.
eye	—*su(tl)*	*iā'iaksutl*, sore-eyed.
face	—*u(tl)*	*hi'tlutl*, face
		hōk·ō'ma, mask = hollow thing used for face.
to fetch, to get	—*itl*	*hā'-umitl*, to fetch food.
foot	—*qte*	*tᴇtē'iqtim*, big toe, = elder brother of feet.
full (solid objects)	—*tsō*	*ha-u'mtsō*, containing food.
to go to	—*ās*	*ha-uā's*, to go to eat.
hand	—*nuk*	*iākiā'kᴇnuk*, sore hands.
hanging	—*pē*	*hayū'pē*, ten hanging ones.
head, point	—*k·ē*	*a'sk·ē*, bald-headed.
hind part	—*ak·tlē*	*hita'k·tlē*, hind part.
inside	—*tsō*	*a'k·tsō*, large bag.
into, inside	—*tsēitl*	*iatstsē'itl*, to enter = to walk into.
inside of house	—*itl*	*t'ē'kuitl*, to sit down on floor.
inside of mouth	—*tsuk·a*	*iā'ktsuk·a*, sore inside of mouth.
inside of man (male)	—*ak·tl*	*ta'ak·tl*, splinter in flesh.
inside of woman	—*suqtl*	*ōk·suqtl*, woman, being happy.
instrument	—*yek·*	*tla'tc'yek·*, chisel.
liquid	—*sit*	*tcamā'ssit*, sweet liquid (molasses).
looking like	—*kuk* (with reduplication)	*sī'sitskuk*, rice = similar to maggots.
		īī'ahkuk, it looks large.
made of	—*tin*	*iniksētin*, made of wood.
just made, new	—*k·ak·*	*tlā'mak·ak·*, new canoe.
man, people	—*ath*	*ō'ath*, people of a certain place.
		mā'ptoqsath, warrior.
middle	—*winis*	*tā'winis*, to erect vertically in centre.
mouth	—*ksu(tl)*	*iā'kuksutl*, with sore mouth.
neck	—*ini(tl)*	*iā'kunitl*, with sore neck.

nose, point	—*ahta*	*a'nēhtēis*, with short nose. *hōpaa'hta*, with round point.
not seen	—*tce*	*Sū'anitctce*, Sanitch, a country one has never seen.
to obtain	—*yep*	*ūqyep*, to find.
obtained	—*ukt*	*nuc'u'kt*, obtained at potlatch.
on a long thing	—*k'uanEs*	*t'ē'k'uanEs*, to sit on long thing.
on round thing	—*k·oas*	*t'ē'k·oas*, to sit on round thing.
one another	—*statl*	*tsu'k·statl*, to strike one another.
out of	—*kusta(s)*	*iatskustas*, to walk out of.
outside of round thing	—*im(tl)*	*hī'tlimtl*, outside of round thing.
outside of house, in woods	—*as*	*tlū'as*, outside. *t'ē'as*, to sit in woods on ground.
to take part in	—*akstē*	*tsēa'kstē*, to take part in a conversation.
to partake of something	—*ēis*	*tlō'mahs'ēis*, to drink warm water.
people of one family	—*utskui*	*hū'-uiahutskui*, chief families.
place where something is done regularly	—*utl*	*hawū'utl*, table = eating place.
place of	—*nit*	*matlnit*, place of coldness.
to play with	—*snaūtl*	*hinemiHsnaūtl*, to play with HinemiH (a mask).
to pretend	—*tē'itla*	*wēitctē'itla*, to pretend to sleep.
to possess	—*nak*	*tlūtcnak*, to have a wife, to be married.
quality of	—*mis*	*tcimiqtu'kmis*, avarice.
receptacle	—*sEts*	*ku·csEts*, pipe = tobacco receptacle.
relationship	—*ēk·sō*	*nuwē'k·sō*, father.
road	—*tcik*	*uēhēiatcik*, close in shore (from *uē'hēis*, bush).
season	—*ēitc*	*tlōp'ē'itc*, summer = warm season.
season when something is done	—*patl*	*k'ok·patl*, hunting season.
to separate	—*atō*	*makatō*, to sell = to separate by trading.
side	—*pa*	*k·atspū*, left side.
side	—*āk*	*nunatū'ak*, paddle steamer = wheels on sides. *papē'nakum*, ear ornament; *pan* ornament, *-ak* side, *-um* used for.
side of body	—*as*	*k·atsū'as*, left side.
small	—*is*	*anū'h'is*, small.
smell	—*puk·s*	*tca'maspuk·s*, sweet smell.
son of	—*mit*	*A'tucmit*, son of Atuc.
sound of	—*atuk*	*k·oa·tsa'tlatuk*, nice sound.
stone	—*a*	*t'ēū'a*, to sit on a stone.
surface of water	—*tcict*	*hi'natcict*, surface of water.
drifting on water	—*matlnē*	*mū'matlnē*, European = house adrift on water.
	—*matlē*, Tlaōkath	*mū'matlē*, European.
taste	—*p'atl*	*tca'masp'atl*, sweet taste.
thing	—*tup*	*ēhtup*, whale = big thing. *tī'tltup*, devilfish = bait thing.
through	—*suē*	*tu'qsuē*, to jump through.
time when something will happen	—*ikk·ō*	*mōtlu'kuikk·ō*, when it will be high water.
time, when something happened	—*uitk·*	*mōtlukuitk·*, when it was high water.
top, end, ahead	—*pē*	*ōpē*, ahead of. *mū'pēas*, house on top of hill (*-as*, outside, country).
towards	—*tsaqtik*	*aptsaqtuk yū'ē*, fair wind.
tree, wood	—*mapt*	*k·atmapt*, oak = hard wood.
underneath	—*āpoa*	*hitū'poas*, underneath in woods.
useless, fragment, &c.	—*tskui*	*ta'qtskui*, saliva = useless water. *ki'tltskui*, fragment.

to become useless	—*kuitcitl*	*inikkuitcitl*, to be burnt.
to make useless	—*kuiap*	*inikkuiap*, to burn.
usitative	—*ēik*	*hawī'k*, always eating.
voice	—(*k·*)*ē'iutl*	*pick·ē'iutl*, bad, croaking voice.
woman	—*ak·sup*	*Heheskwia'k·sup*, Heskwiath woman.

COMPARISON BETWEEN THE KWAKIUTL AND NOOTKA LANGUAGES.

From what has been said regarding the formation of words in these languages it is clear that a mere comparison of words cannot bring out the similarity or dissimilarity between the two languages. Their similarity is most clearly brought out in comparing the methods of formation of words.

1. In both languages only suffixes are used for forming words. Among these the following are found to have similar phonetic elements :

	Kwakiutl	Nootka
in boat	—*aqs(a)*	—*ahs.*
out of boat	—*oltla*	—*ōtlta.*
beach	—*is*	—*is.*
having	—*nak*	—*nuk.*
inside of house	—*itl*	—*itl.*
head, top	—*k·ēa*	—*k·ē.*
point, end	—*pē*	—*pē.*
people	—*itq*, -*ēnoq*	—*ath.*
stone	—*a*	—*a.*
underneath	—*apoa*	—*ā'poa.*
receptacle	—*atsē*	—*sets.*
round things	—*k·am*	—*k·am.*
long things	—*ts'ak·*	—*ts'ak·.*
female	—*ak·sup*	—*ak·sᴇm*, -*ak·s*, -*k·as.*
drifting on surface	—*tlē*	—*matlnē*, -*matlē.*
to partake of	—*es*	—*ēis.*
through	—*sīoa*	—*suē.*
hind part	—*ak·tlē*	—*ak·tlē.*
inside	—*tsoa*	—*tsō.*
rim	—*ēsta*	—*īts.*
smell	—*p'a'la*	—*puk·s.*
taste	—*p'a*	—*p'atl.*
upward	—*usta*	—*kusta.*
liquid	—*sta*	—*sit.*
outside of house	—*as*, -*ils*	—*as.*
side of	—*us*	—*as.*

In Nootka these suffixes may be made independent words by being appended to the stems ō-, a certain (definite), *ōc*- some (indefinite), *hit*- and *hitl*-, that; *ap*-, probably side. In Kwakiutl the suffixes may be made independent nouns by being affixed to *ō*-, *ōk*-, *ōs*-, *hi*-, *awī*-, the separate meanings of which have not become clear to me. They are, however, used in exactly the same way as the corresponding stems in Nootka.

2. The following words, other than pronouns, are alike :

	Kwakiutl	Nootka
hair	*hap-*	*hap-*
to fly	*matē(la)*	*mā'matē* (reduplicated) bird.
chief	*hē'was*, *hē'mas*	*haū'ia.*
ear	*p'ᴇsp'ē'yō*	*p'a'p'ē.*
eye	*k·a'yak·s*	*k·a'sē.*
star	*t'ō't'ōa*	*tat'ū's.*
wind	*yū-*	*yū'ē.*
moon	*nō'si*	sun, *nās.*
earth	*tsqams*	*ts'ak'u'mts.*
salt	*tᴇmp*	*tō(p).*
stone	*nī'kye*	*nu'ksi*, *mu'ksi.*
to drink	*nak·-*	*nak·.*
to eat	*ham-*	*ha-uw-*

	Kwakiutl	Nootka
snow	*kuī'sa*	*koī's.*
root	*tlō'pakh*	*tlō'p'atc.*
wedge	*tlā'nut*	*tlā'nut.*
mother	*abō'k*	*amakō'* (Nitinath).
hollow opening	*ak·*	*ak·.*
not	*(w)ī, (h)ī, (kn)ī*	*(w)ī, (h)ī.*
to jump	*tuq—*	*tuq—*
one	*nem*	*nup.*
two	*mātl*	*ātla.*
four	*mū*	*mō.*
five	*sky'a*	*sū'tca.*
seven	*atlilū'*	*a'tlpō.*
times	*—penhit*, H. *—p'ana*, K.	*—pit.*

While many of these may be loan-words, it is highly improbable that any of the suffixes should be borrowed.

3. Pronouns:

	Kwakiutl	Nootka
I,	*nō'gua*	*sē'ya.*
thou,	stem: *sō*	*sō'wa.*
we,	*nō'guants.*	*nē'wa.* *nō'wa*, Kayō'kath.

Personal suffixes of verb, indicative.

	Kwakiutl	Nootka
I,	*—nōgua*, H. *—in*, K.	*—s(ic)*, Tl. *—ah* Ts.
thou,	*—sō*, H. *—es*, K.	*—itsk*, Tl. *—ēits*, Ts.
we,	*—en(ts) —en(uq).*	*—nic*, Tl. *—ine*, Ts.
you,	*—itsō*, H.	*—itsōc*, Tl. *—ēitsō*, Ts.

4. The formation of the collective form of nouns, of plural of verbs, the inflection of adverbs accompanying verbs instead of the verb is the same in these two languages and in the Salish. (The exclusive use of suffixes is not found in the latter.) The peculiar use of the negation in compounding words is also common to the two languages.

5. The phonetics are probably the same; the few instances in which a word begins with several consonants in Kwakiutl seem all to be due to an elimination of vowels, and these words are found in very rare instances only in the southern dialect.

The similarity of structure of the two languages is far-reaching. The words which may be referred to the same root are so numerous, considering the small amount of available material, that the conclusion seems justified that both have sprung from the same stock.

THE SALISH LANGUAGES OF BRITISH COLUMBIA.

As at least one Salish language, the Salish proper, is comparatively well known, through the efforts of the Jesuit missionaries,[1] I confine myself to a few brief remarks on the languages belonging to this stock. I select the Bilqula, SnanaimuQ, Shushwap, Stlā'tlumH, Okanā'k·ēn, as representing the principal types of the great number of dialects.

Bilqula.

The plural of nouns is formed in various ways:

1. Singular and plural have the same form: beaver, *kōlō'n.* deer, *supanī'tl.* stone, *tqt.*
2. The plural is formed by the suffix *—uks*: woman, sing. *hnac*, pl. *hna'cuks.*
3. „ „ „ *—th*: man, sing. *tl'u'msta*, pl. *tl'umsta'th.*
4. „ „ „ reduplication: tree, sing. *stn*, pl. *stntn.*

[1] See Mengarini's *Grammatica Linguæ Selicæ;* Giorda, *Dictionary of the Calispelm.*

An article is used extensively; it precedes nouns and adjectives, and stands between the substantive and the verb. It has a masculine and feminine gender.

the bird (1) flies (2), *tsītsipē'* (1) *ti sī'ʜsek·* (2)
my grandmother, *tsi kikia'tstsʜ.*

It seems that only females of men and animals have the feminine article.

The numerals have various classes:

—	Men	Animals, fathoms, blankets	Long objects, days	Box, vessel	Round things, houses
1	*nōnmaū ē*	*smā'o*	*smau'aaq*	*mau'atl*	*smā'otl*
2	*nutlnō'sau*	*tlnōs*	*tlnōsā'aq*	*tluā'satl*	*tlnō'sutl*
3	*naasmō'sau*	*asmō's*	*asmōsā'aq*	*asmō'sutl*	*asmō'sutl*
4	*numō'sau*	*mōs*	*mōsā'aq*	*mō'sutl*	*mō'sutl*
5	*nuts'ē'ʜ'oa*	*ts'ēǫ*	*ts'ēǫā'aq*	*ts'ē'ǫutl*	
6	*nutqō'tlau*	*tqōtl*	*tqōtlā'aq*	*tqō'tlutl*	

Numeral adverbs are formed by the suffix —*anᴇ'msts.*

Personal pronouns are:

I, *ens.* we, *ʜmitl.*
thou, *inō.* ye, *tl'ōptl.*
he, *t'aiʜ.* they, *t'ats.*

The possessive pronouns are twofold:

my, *enstl.* our, *ʜnūtl.*
thy, *inōtl.* your, *tl'ōptl.*
his, *t'aiʜtl.* their, (?)
my house, *enstl ti sōtl.*

The second form is suffixed:

my—*ts.* our—*itl.*
thy—*no.* your—*apa.*
his—*s.* their—*auts.*
my grandson, *stlēmtsts.*
thy grandson, *stlēmtsnō.*

When the noun is a feminine the possessive pronoun takes the ending—*ʜtsʜ*:

my granddaughter, *stlēmtstsʜtsʜ.*
thy granddaughter, *stlēmtsnōʜtsʜ.*

The intransitive verb is inflected either by means of suffixes or by joining the pronoun to it by the article. A third form originates by repetition of the pronoun.

to go, *tl'ap.*

1st person sing.	*tl'apsts*	*ens ti tl'ap*	*tl'apsts ti ens.*
2nd ,, ,,	*tl'apnuts*	*inō ti tl'ap*	*tl'apnuts ti inō.*
3rd ,, ,,	*tl'aps*	*t'aiʜ ti tl'ap*	*tl'aps ti ʜt'aiʜ.*
1st ,, plur.	*tl'apītl*	*ʜmītl ua tl'ap*	*tl'apitl ua ʜmītl*
2nd ,, ,,	*tl'apapa*	*tl'ōptl ua tl'ap*	*tl'apapa ua tl'ōptl.*
3rd ,, ,,	*tl'apauts*	*t'ats ua tl'ap*	*tl'apauts ua ats.*

The pronominal object is incorporated in the pronoun. My collection is, however, not sufficient to give the transitive verb in a paradigmatic form.

Snanaimuǫ.

The noun has no separate forms for singular and plural. It has a distributive formed by reduplication, epenthesis, or diæresis.

	Distributive.	Diminutive.
deer, *smē'yᴇç.*	*sᴇmē'yeç.*	—
deer, *hâ'pet.*	*halâ'pᴇt.*	—
mink, *tcitcī'ek·an.*	*tcilᴇtcī'ek·an.*	—

	Distributive.	Diminutive.
whale, *k·u'nes.*	*k·ōkuī'nis.*	—
raven, *spâl*	*spElpâ'l.*	—
crow, *k·Elā'k·a*	*k·Elk·Elā'k·a.*	—
river, *stâ'lo.*	*stEltâ'lō.*	*stā'tElō.*
salmon, *stīä'atltEm*	*stsEltsä'atltEn.*	*stcä'tsElatltEn.*
post, *k·ā'k·En.*	*k·ä'lak·En.*	*k·ä'k·k·En.*
frog, *wu'qas.*	*hāuwē'qas.*	*wē'wēqas.*
flower, *spä'k·Em.*	*spä'lak·Em.*	*spä'pk·Em.*
house, *lä'lEm.*	*lalä'lEm.*	*lē'lEm.*

An augmentative is formed by similar processes: *snE'quitl*, boat; *snō'quōtl*, large boat.

The numerals have two classes; one for counting men, the other for all other objects:

Counting	Men
1, *nE'ts'a.*	*nānEts'a.*
2, *yisa'le.*	*yā'isEla.*
3, *tlēq.*	*tlquä'la.*
4, *qaā'çEn.*	*qaçä'la.*
5, *tlk·ä'tsEs.*	*tlk·atsä'la.*

The numerals are not frequently combined with nominal affixes, as is the case in the dialects of the interior.

Personal pronouns:

I, *äns.*	we, *tEtlnē'mEtl.*
thou, *nō'ua.*	you, *tEtlwE'lap.*
he (present), *tçä.*	they (present) m. and f., *tsä'lēi.*
he (absent), *kçä.*	they (absent) m. and f., *kçä'lei.*
she (present), *çä.*	
she (absent), *ktlä.*	

POSSESSIVE PRONOUN.

Singular			Plural		
	Present	Absent		Present	Absent
my	Masc. *tsEn*	*kçE*	our	Masc. *tsE—tst*	*kçE—tst*
	Fem. *çEn*	*ktlE*		Fem. *sE—tst*	*tlE—tst*
thy	Masc. *tsä'Es*	*kçä'Es*	your	Masc. *tsä'E—lap*	*k'un—lap*
	Fem. *sä'Es*	*ktlä'Es*		Fem. *sä'E—lap*	*ksEn—lap*
his	Masc. *tsE—stä*	*kçE—s*	their	Masc. *tsE—stlä'lēi*	*kçE—stä'lēi*
	Fem. *çE—stçä*	*ktlE—s*		Fem. *sE—stlä'lēi*	*tlE—stsä'lēi*
her	Masc. *tsE—sçä*	*kçE—s*			
	Fem. *çE—sçä*	*ktlE—s*			

THE VERB.

The verb is inflected either by means of suffixes or by auxiliary verbs. The tenses are expressed by suffixes, *—ētl* denoting the past, *—tsEn* the future.

sick: present k·'ä'k·'ēi, *future* k·'āk·'ē'itsEn, *past* k·'āk·'ē'iētl.

Verbs form a plural as well as nouns; it is, however, not always used, the plural being expressed sufficiently clearly by the suffixes. In solemn speeches the plural forms are always used:

Sick	Present	Future	Past
Singular, 1st person	k·'āk·'ē'i-tsEn	k·'āk·'ē'i-tsEn-tsE	k·'āk·'ēi-ētl-tsEn
2nd „	k·'āk·'ēi-(E)tc	k·'āk·'ēi-tsEn-(E)tc	k·'āk·'ēi-ētl-(E)tc
3rd „	k·'āk·'ē'i	k·'āk·'ē'i-tsEn	k·'āk·'ēi-ētl
Plural, 1st „	k·'ā(i)k·'ē'i-tst	k·'ā(i)k·'ē'i-tsEn-tst	k·'ā(i)k·'ēi-ētl-tst
2nd „	k·'ā(i)k 'ēi-(E)tsäp	k·'ā(i)k·'ēi-tsEn-(E)tsäp	k·'ā(i)k·'ēi-ētl·(E)tsäp
3rd „	k·'āik·'ēi	k·'āik·'ēi-tsEn	k·'āik·'ēi·-ētl

The following future forms indicate the existence of another future:—

I shall eat, atltEn-tEn-tsE. *I shall be sick*, k·'āk·'ēi-tEn-tsE.

Inflection by means of auxiliary verbs is very frequent.

Sick	Present	Future	Past
Sing., 1st pers.	(n)ē-tsEn k·'ā'k'ēi	näm-tsen k·'ā'k·'ēi	(n)ētl-tsE(n) k·'ā'k·'ēi
2nd „	(n)ē-(E)c „	näm-(E)tc „	(n)ētl-(E)tc „
3rd „ masc.	(n)ē(-tsE) „	näm „	(n)ētl „
„ „ fem.	(-çE)		
Plural, 1st „	(n)ē-tst k·'ā(i)k·'ēi	näm-tst k·'ā'(i)k·'ēi	(n)ētl-tst k·'ā(i)k·'ēi
2nd „	(n)ē-(E)tsäp „	näm-(E)tsäp „	(n)ētl-Etsäp „
3rd „	(n)ē k·'äik·'ēiētltEn	näm k·'äik·'ēi	(n)ētl-k·'ā'ik·'ēi-ētltEn

The auxiliary verb of the future tense means 'to go,' that of the present and past tenses *ē* is evidently the verbum substantivum. Frequently the particle *p'a* is added to the inflected forms. I am unable to explain its meaning.

I am sick, k·'ak·'ē'i-tsEn p'a.
ē-tsEn p'a k·'āk·'ē'i.
I have been sick, ētl-tsE p'a k·'ā'k·'ēi.
it is he, nētl p'a.

The initial *n* is used if the person spoken of is absent. In the third person a distinction is made between the person being present, absent, and invisible, and absent and visible.

he is sick (*he present*), ē-p'a k·'āk·'ei.
„ (*he absent, invisible*), nē p'a k·'āk·'ēi.
„ (*he absent, visible*), ä'et p'a k·'āk·'ēi.
they are sick (*they present*), ē p'a k·'ā'ik·'ēi,
or ē p'a k·'āk·'ē'i-ētltEn.

The present tense formed with the auxiliary verb serves as a perfect:

I sit down, ā'mat-tsEn. *I lie down to sleep*, ē'EtEt-tsEn.
I am sitting, ē-tsEn āmat. *I am asleep*, ētsEn ē'EtEt.

When the initial *n* is used in the first and second persons the verb refers to a past or future state or action. This is probably caused by the expression of absence which in these persons cannot be in space, but must be in time.

A double future is sometimes formed by using the future of the auxiliary verb:

I shall be sick, näm-tsEn-tsE k·'ā'k·'ēi.

The active verb, when it has no pronoun for object, is inflected in the same way as the neutral verb, either by suffixes or by auxiliary verbs. If it has a pronominal object the latter is expressed by a suffix to the verb, and the latter is then treated exactly like an intransitive verb. This close connection of the activity and the object acted upon, while the subject remains independent of this combination, is very interesting. It explains also the syntactic peculiarity that the subject is attached to the adverb, while the object is attached to the verb. I collected only a small portion of the objective forms of the verb.

Object	Singular			Plural
	1st person	2nd person	3rd person	1st person
1st per. sing.	—	—āmc	—āmc	—
2nd „ „	—âma	—	—	—âma
3rd „ „	—uq	—uq		
1st „ plural	—			
2nd „ „	—ā'la			
3rd „ „	—t(ētltEn)	—	—qus	

These forms are treated exactly as the intransitive verb:

I see you, lälemaçâ'ma-tsEn (p'a),
or (n)ē'tsE(n)(p'a) lälEmaçâ'ma.
I shall see you, lälEmaçâ'ma-tsEn-tsE(p'a) &c.

IMPERATIVE.

Singular: *write!* qa'lEm-tla!
Plural: *write!* qalEmä'-tla!

The imperative is frequently circumscribed by: *it is good that you—*, ai—.

take care! ai ku siâ!
take pity upon me! ai(p'a) kuns tsQuī'mEçâma!

The indicative is frequently used instead of the imperative.

Don't go! (*plural*) au'atsEp näm (*verbatim, you do not go*).

Shushwap.

The principal peculiarities of the Shushwap are the occurrences of an exclusive and inclusive form of the plural and the great frequency of irregular plurals.

The distributive form of the noun is formed by amplification of the stem, generally by reduplication. Irregular distributives of nouns are rare. Plurals of adjectives and verbs are formed in the same way. In the latter the plural is frequently derived from a separate stem:

boy,	*tūwē'ut.*	distributive,	*tūtuwē'ut.*
country,	*tEmē'Q.*	"	*tEmtEmē'Q.*
dog,	*sk·ā'qa.*	"	*sk·aqk·ā'qa.*
head,	*ska'pk·En.*	"	*sk·Epka'pqEn.*
house,	*tsitQ.*	"	*tsītsī'tQ.*
man,	*sk·a'lEmuQ.*	"	*sk·ā'lk·ElEmuQ.*
old man,	*stlq'ā'am.*	"	*stEqtlq'ā'am.*
old woman,	*gīē'ia.*	"	*gigīē'ia.*
woman,	*nō'qonuq.*	"	*noqnō'qonuq.*
bad,	*k'ēst.*	"	*ky'Eskēst.*
good,	*la.*	"	*lEla'.*
strong,	*rulral.*	"	*rilrilra'l.*
old,	*kā'wulq.*	"	*kukā'wulq.*
to come,	*stl'aq.*	plural,	*stEtla'q.*
to dance,	*k·oiē'lQ.*	"	*k·oik·oiē'lQ.*
to go,	*k·utsā'ts.*	"	*k·utsā'ats.*
to run (animal),	*noq.*	"	*no'qnoq.*
to sing,	*sitsē'nEm.*	"	*sisitsē'nEm.*
to stand,	*stsilā'ut.*	"	*stsistsilā'ut.*

Irregular plurals:

small,	*kuiē'esa.*	"	*tsitsitsEma'Et.*
to cry,	*ts'ōm.*	"	*k·oa'k·t.*
to laugh,	*ōlē'lEm.*	"	*qoiqoā'yōs.*
to run (man),	*na'wulq.*	"	*toā'wa.*
to sit (v.a.),	*amō't.*	"	*tlā'kElQ.*
to sit (v.n.),	*mōt.*	"	*tsiā'm.*
to return,	*tsīra'p.*	"	*tskitsQ.*
to sleep,	*pElē't.*	"	*QEmkā'ut.*
to speak,	*kotō't.*	"	*k·oā'les.*
to walk,	*kōwā'tEm.*	"	*Qusā't.*

There is no indication of the existence of a gender.

Diminutives are formed by amplifications of the stem:

girl, *Qā'utEm.*	distributive, *QuQāutEm.*
little girl, *QuQā'QutEm.*	" *QuQQā'QutEm.*
lake, *pasi'tlkua.*	small lake, *papsi'tlkua.*

Augmentatives are formed by a similar process:

stone, *sqanq*. large stone, *sqaqa'nq*.

There are various classes of numerals:

—	Counting	Men	Round, flat objects	Days
1	*nek'ō*	*nuk'uā'tl*	*nuk·'ō'tl*	*nuk·'askt*
2	*sesā'la*	*tiksā'ha*	*sil'ō'tl*	*silaskt*
3	*ketlā's*	*tiketlā's*	—	*kilaskt*
4	*mōs*	*tmō'semes*	—	*mesaskt*
5	*tsīlkst*	*tktsī'ltsikst*	—	—
6	*tkmākst*	*tkmā'k·makst*	—	—

The numerals may be composed with any nominal affix:

1 head, *nuk·'ō's*.
1 hand, *nuk·'a'kst*.
1 water, *qenuk·'a'tkua*.
1 piece of clothing, *nuk·'a'lek s*.
1 tooth, *qnuk'ā'ns*.
1 road, *qnuk'ā'us*.
&c.

the first, *qtak·s*.
the second, *kīkat ne qtak·s* = next to first.
the third, *kīkat ne skemā'os* = next to middle.
the fourth, *kīkat ne sketla's* = next to three.

once, *nesqetā'k·s*.
twice, *nesesā'les*.
three times, *neskitlā'sts*.
four times, *nesmō'sts*.

PERSONAL PRONOUN.

I, *antsā'wa*.
thou, *anū'ē*
he, she, *nuē's*.
we, inclusive, *utlnuē'kt*.
we, exclusive, *utlnuē'eskuq*.
you, *utlnuē'emp*.
they, *utlnuē'es*.

POSSESSIVE PRONOUN.

my house, *ntsitq*.
thy house, *ratsitq*.
his house, *tsitqs*.
our (inclusive) house, *tsitqkt*.
our (exclusive) house, *tsitqskuq*.
your house, *tsitqump*.
their house, *tsi'tsitqs*.

In some cases the initial *r* of the second person singular is omitted.

it is mine, *ntsātswa*.
it is thine, *asō'ten*.
it is his, *sō'tens*.
it is ours (inclusive), *sō'tenkt*.
it is ours (exclusive), *sō'tenskuq*.
it is yours, *sōtene'mp*.
it is theirs, *sō'tens*.

The verb is generally inflected by the means of auxiliary verbs, which express the tenses with great nicety.

I am a Kamloops, *stkamlō'psemqk·ēn*.
thou art ,, ,, *stkamlō'psemqk*.
he is ,, ,, *stkamlō'psemqk*.
we (inclusive) are Stkamlōpsemq, *stkamlō'psemqkt*.
we (exclusive) ,, ,, *stkamlō'psemqkuq*.
you ,, ,, *stkamlō'psemqkp*.
they ,, ,, *stkamlō'psemqk*.

In the plural the verb takes generally its plural form:

I am sick, *kyeapkēn* you are sick, *kyekya'pkp*.

Statements are generally made in a mild, dubitative form. Instead of, he is sick, *kyēa'p*, one says, *kyēa'pnuk*, I think he is sick.

to eat, *ē'tlen*.

Perfect: *me ē'tlenkēn*, I have eaten.
Imperfect: *ōaqa ē'tlenuan*, I was eating.
Future: *ma ē'tlenkēn*, I am going to eat.

TRANSITIVE VERB.

Subject.

Object	Singular		
	1st person	2nd person	3rd person
1st person singular	—	—*tsā'tsEmuQ*	—*tsā'tsEms*
2nd „ „	—*tsēn*	—	—*tsēs*
3rd „ „	—*tā'tEn nuē's*	—*tāq*	—*tās*
1st „ plur. incl.	—	—	—*tā'lEs*
1st „ „ excl.	—	—*ta'qkuq*	—*tā'skuq*
2nd „ „	—*tō'lEmEn*	—	—*tō'lEms*
3rd „ „	—*tā'tEn utl nuē's*	—*tāq utl nuē's*	—

Object	Plural			
	1st per. incl.	1st per. excl.	2nd person	3rd person
1st person singular	—	—	—*tsā'tsilp*	—*tsā'tsEms*
2nd „ „	—	—*tsē't*	—	—*tsēs*
3rd „ „	—*tām nuē's*	—*tā'mkuq nuē's*	—*tāp*	—*tās*
1st „ plur. incl.	—	—	—	—*tā'lEs*
1st „ „ excl.	—	—	—	—*tā'skuq*
2nd „ „	—	—*tō'lEmt*	—*tā'pkuq*	—*tō'lEms*
3rd „ „	—	—*tsēt*	—*tāp*	—

Stlā'tlumH.

The noun has no separate forms for singular and plural. The distributive is formed by reduplication of the stem; the diminutive and augmentative are also amplifications of the stem. There is no gender.

The numeral has several classes. In counting men the numeral is reduplicated. In counting animated beings it is amplified in another way. It may be compounded with any of the innumerable affixes.

—	Counting	Men	Animate
1	*pE'la*	*pā'pElāa*	*pE'pEla*
2	*ā'nuEc*	*Enā'nuEc*	*ā'anuec*
3	*kāEtlā'c*	*kkā'actlā'c*	*kāatlE'ls*
4	*qoō'tcin*	*qōq'ō'tcin*	*q'ō'otcin*
5	*tcī'likst*	*tcī'ltcilikst*	*tci'tcilikst*
6	*tl'a'k·Emkist*	*tl'ak·E tlk·a'mkist*	*ɫl'ā'tlk·amk'st*
7	*tcūtlaka*	*tcutltclakā'a*	*tcū'tclaka*

I mention the following compounds:

1 canoe, *pa'lōluitl.*
1 house, *pa'l'altc.*
1 tree, *pa'l'aluk·.*
1 water, *pal'ā'tk·oa.*
1 country, *pal'ō'lmuQ.*
1 fire, *pa'lēkup.*
1 day, *pal'ask·ē'it.*
1 stone, *pa'l'altc.*
1 dollar, *pa'l'ōca.*
&c.

Personal pronouns are:

I, *cEintca.*
thou, *snō'a.*
he, *cnē'itl.*
we, *nucnē'mutl.*
you, *snōla'p.*
they, *wucnē'itl*

POSSESSIVE PRONOUN.

my, *n*—
thy, —*sua.*
our, —*tlkūtl.*
your, —*lap*

his, —*s.* their, —*ē.*
my grandfather, *ndz'i'tsEp'a.*
our grandfather, *dz'i'tsEp'atlkātl.*

Intransitive Verb.

I am a European (*ca'ma*),	*ca'matlkān.*	we are Europeans,	*cā'maatlkatl.*
thou art ,,	*ca'matlkāuq.*	you ,,	*cā'matlka'lap.*
he is ,,	*cā'maatē.*	they ,,	*cā'mawit.*

The verb is in many cases inflected by means of auxiliary verbs:

I am eating, *waEtlkān ē'tlEn* (*ē'tlEn*, to eat).
I am just sitting down to eat, *ē'tlEntlkān.*
I have eaten, *pElā'ntlkān tō wa ē'tlEn.*
I was just going to eat, *hō'itlkan ci'na ē'tlEn.*
I was eating (*i.e.*, when you came), *ē'wa an ē'tlEn.*

Transitive Verb.

Subject.

Object	Singular		
	1st person	2nd person	3rd person
1st person singular .	—	—*ckā'uQ*	—*cac*
2nd ,, ,, .	—*cītlkān*	—	—*cī'hac*
3rd ,, ,, .	—*kan*	—*kāuQ*	—*as*
1st ,, plural .	—	—*ōmōtlkāuQ*	—*tō'mōtlas*
2nd ,, ,, .	—*ō'mōtlkan*	—	—*tamā'lapas*
3rd ,, ,, .	—*ānitlkan*	—*ōwitkā'uQ*	(?)

Object	Plural		
	1st person	2nd person	3rd person
1st person singular .	—	—*cka'lap*	—*calitas*
2nd ,, ,, .	—*cīm*	—	—*cī'hasuit*
3rd ,, ,, .	—*Em*	—*ka'lap*	—*ē'tas*
1st ,, plural .	—	—*ō'mōtlka'lap*	—*ō'mōlitas*
2nd ,, ,, .	—*tEmtlkā'lap*	—	—*tamalapā'suit*
3rd ,, ,, .	—*ta'nEmuit*	—*ka'lapuit*	(?)

It is of great interest to see that whenever the verb is inflected with an auxiliary verb, the latter takes the endings of the intransitive verb, while the transitive verb retains the incorporated object. This is the case also in the dialects of the coast, and in Shushwap, but I have not given a paradigm, as I have no complete set of forms in the other dialects.

Subject.

Object	Singular and Plural	
	1st person	2nd person
1st person singular . .	—	—*c*
2nd ,, ,, . .	—*cin*	—
3rd ,, ,, . .	—	—
1st ,, plural . .	—	—*tomotl*
2nd ,, ,, . .	—*tōmotl*	—
3rd ,, ,, . .	—{*uit* / *ta'nitan*}	—*uit*

Okanā'k·ēn.

Nouns have a distributive which is formed by amplification of the stem:

Indian,	*sk·ēlQ.*	distrib.	*sk·Elk·ē'lQ.*
man,	*sk·EltEmē'Q.*	„	*sk·Elk'EltEmē'Q.*
boy,	*tEtuwē't.*	„	*tō'tuit.*
to give,	*Quē'tsiQt.*	plural,	*sQuē'tsiQtē.*
to tell a lie,	*smā'lElaqāa.*	„	*smElmālElaqā'a.*
sick,	*sk·'E'lElt.*	„	*sk·'ilk·'ē'ltQ.*

Irregular plurals are not as frequent as is Shushwap, but still very numerous:

woman,	*tk·itlEmē'luq,*	distributive,	*cmāmEē'm.*
boy,	*sQuinu'mtQ.*	„	*spElā'l.*
baby,	*skukui'mElt.*	„	*sītsEm'ā'la.*
to run,	*k·ē'tciliQ.*	plural,	*Qē'tEmēst.*
to sleep,	*ītQ.*	„	*ts'ātQē'liQiQ.*
to speak,	*k·ulkoē'lElt.*	„	*sk·oak·oa'l.*
to stand,	*aksuwē'Q.*	„	*t'ōwē's.*
to walk,	*Qui'stQ.*	„	*tekoō'tuwē.*

NUMERALS.

Persons	Other objects	Persons	Other objects
1. *k·Enāk·s*	*nak·s*	4. *k·Emō'sEmis*	*mōs*
2. *k·asEasī'l*	*acī'l*	5. *ktcīltcilkHst*	*tcīlkHst*
3. *k·ak·āatlī'c*	*k·ā'tlēc*	6. *ktak·tāk·EmkHst*	*t'ā'k·EmkHst*

Besides this numerals can be composed with any of the numerous affixes of the language:

two houses, *aslē'tlQ.*
two canoes, *aslē'utl.*
two trees, *aslā'luk·.*
two faces, *asElū's.*
two fires, *aseli'selp.*
two days, *aselā'sk·t.*
two stones, *aseli'sQEn.*
two blankets, *asElī'tsa,* &c.

Personal pronouns are:

I, *Entā'kEn.*
thou, *hānuē'.*
he, *tcinī'tl.*
we, *mnē'mltit.*
you, *mnē'mtlEm.*
they, *mnē'mtciliQ.*

The possessive pronouns are:

my, *in—.*
thy, *ān.*
his, *hē—s.*
our, *—tEt.*
your, *—mp.*
their, *—sliQ.*

my father, *in lEē'u.*
his father, *hē lEē'us.*
our father, *lEē'utEt.*

When the noun begins with an *s*, *ī* and *ā* stand for the first and second persons:

my mother, *īsk'ō'i.*

INTRANSITIVE VERB.

I am sick, *kines k·'ē'lEltQ.*
thou art sick, *k'uts k·'ē'lEltQ.*
he is sick, *sk·'ē'lEltQ.*
we are sick, *kūs k·'ē'lEltQ.*
you are sick, *ps k·'ē'lEltQ.*
they are sick, *sits k·'ē'ltQilQ.*

The difference between the verbs with definite and indefinite object, described by Mengarini in his Salish grammar, is found here also:

I work, *kinEs k'ō'lEm.*
thou workest, *k'uts k'ō'lEm.*
he works, *k'ō'lEm.*
&c.

I work at it, *hēts k'ō'lEstEn.*
thou workest at it, *hēts k'ō'lEstQ.*
he works at it, *hēts k'ō'lEstc.*
we work at it, *hēts k'ō'lEstEm.*
you work at it, *hēts k'ō'lEstEp.*
they work at it, *hēts k'ō'lEstcilQ.*

These brief notes will suffice to give an idea of the general character of the various dialects of the Salish languages. The principal points of difference are the following. The Bilqula and the Coast Salish have a pronominal gender, masculine and feminine, and distinguish throughout presence and absence. The Shushwap has exclusive and inclusive forms of the first person plural, and a remarkably great number of irregular plurals. The Okanā'k·ēn and Stla'tlemʜ have none of these peculiarities. The Ntlakya'pamuq resembles the Stla'tlemʜ in its structure. It seems that incorporation of nouns is carried to a far greater extent in the dialects of the interior than in those of the coast (see Vocabulary). All the Salish dialects use auxiliary verbs in inflecting the verb.

TERMS OF RELATIONSHIP OF THE SALISH LANGUAGES.

It is rather interesting to compare the systems of terms of relationship in various groups of Salish people, as the systems are fundamentally different. Among the Coast Salish, to whom the Lku'ñgᴇn belong, there is no distinction between relations in the male and in the female line. Relations of males and females are designated by the same term. While brothers and sisters of both parents are designated as uncles and aunts, their wives and husbands are styled 'acquired fathers and mothers.' Cousins are termed and considered brothers, although there exists also a separate name for the relationship. Brothers' and sisters' grandchildren are termed grandchildren. The most peculiar features of the Salish system of relationship, particularly among the Coast Salish, is the use of distinct terms for indirect affinities, when the intermediate relation is alive and when he is dead. This seems to imply that after the death of the intermediate relative the mutual relation between the two indirect relatives undergoes a change.

I give here a table of terms of relationships representing the system of the Coast Salish. It is taken from the Sk·qō'mic dialect.

I. DIRECT RELATIONSHIP.

Great-great-great-grandparent,	*ha-u'kwēyuk·*	great-great-great-grandchild.
great-great-grandparent,	*ts'ō'pēyuk·*	great-great-grandchild.
great-grandparent,	*stc'ā'mik·*	great-grandchild.

sē'el, grand {father, mother, / uncle, aunt} — *ē'mats*, grand {child, / nephew, niece}

mān, father,
tci'ca, mother,

mᴇn, child.
sē'entl, eldest child.
a'nōntatc, second child.
mᴇntcē'tc'it, third child.
sā'ut, youngest child.

kupkuō'pits, brothers, sisters, and cousins together.

kuō'pits, elder {brother, / sister,}, {father's / mother's} elder {brother's / sister's} child.

sk·āk·, younger {brother, / sister,}, {father's / mother's} younger {brother's / sister's} child.

sntc'ō'itl, cousin.

II. INDIRECT RELATIONSHIP.

1. Intermediate Relative alive.

sī sī, {father's / mother's} {brother / sister} — *stā'eatl*, {brother's / sister's} child.

tcEma'c, {wife's / husband's} {cousin, / brother, / sister,}, {cousin's / brother's / sister's} {wife / husband}

sā'aq {son / daughter / father / mother} -in-law.

skuē'was.—If a member of one family has married a member of another his and her relatives call each other *skuē'was*, *e.g.*, step-brother, &c.

2. Intermediate Relative dead.

uotsā'ēqoitl, {father's / mother's} {brother / sister}, *suinēmā'itl*, {brother's / sister's} child.

tcā'iāē, {wife's / husband's} {cousin, / brother, / sister,}, {cousin's / brother's / sister's} {wife / husband.}

slik·oā'itl, {son, daughter, / father, mother} -in-law.

III. ACQUIRED RELATIONSHIP (THROUGH MARRIAGE).

sqsē'el, wife's grand {father, / mother,}, step-grand {father / mother.}

sq'mān, aunt's husband, step-father.
sqtci'ca, uncle's wife, step-mother.
sq'mEn, step-child.

sq'ē'mats, grand {son's / daughter's} {wife / husband.}

sqsā'aq, {wife's / husband's} step {father, / mother,}, step-child's {husband / wife.}

Bilqula.

I have not been able to get a satisfactory collection of terms of relationship from the Bilqula. The following will show, however, that their system differs greatly from that of the Coast Salish. It seems the distinction between the two classes of indirect relationship does not exist.

kō'kpi, {father's / mother's} father, granduncle.

gīgia', {father's / mother's} mother, grandaunt.

mān, father.

stān, mother.

mE'na, child.

siskHsō'm, {father's / mother's} sister.

skHsī, {father / mother / child} -in-law.

stlēmts, grandchild.

talau'sau, married couple.

k·ōalE'm, elder {brother / sister.}

sōaqē', younger {brother / sister.}

sī'sī, {father's / mother's} brother.

Stlā'tlEmH.

There is no distinction between terms of relationship used by male or female. Only terms of affinity are affected by the death of an intermediate relation.

Great-grandparent, *ts'u'pēyuk·*, great-grandchild.

dz'itsp'ā'a, addressed *spā'pea*, {father's / mother's} father.

ku'koāa, addressed *tā'taa*, {father's / mother's} mother.

ē'ematc, grandchild.

sk·ā'tza, father.
skēqedzā'a, mother.
skōzā'a, child.
k·ek·tcik, elder brother.
k·e'qk·eq, elder sister.

cick·'oâ'dz, younger {brother / sister}

k'tāmtc, husband.
cem'ā'm, wife.

cēck·ā'a, {father's / mother's} brother.

stā'a, {father's / mother's} sister.

ctū'niq, {brother's / sister's} daughter.

ck·'cā'a, {brother's / sister's} son.

nē'u, address for husband and wife.

Terms of Affinity.

1. *Husband, viz., wife alive.*

cqunā mt {wife's / husband's} parents call {husband's / wife's} parents.
cā'eqāa, parent-in-law.
ctūtā'tl, son-in-law.
cā'pen, daughter-in-law.
cts'aqt, wife's brother.
ckā'ō, husband's sister.
c'a'ctem, wife's sister and husband's brother.

2. *Husband, viz., wife dead.*

ck'a'lpaa, used for all relatives by marriage after death of husband or wife.

It is a significant fact that one term serves to designate the wife's sister and the husband's brother, who become the wife or husband of the widower, or widow. On the coast, when a masculine or a feminine article is used, the same terms serve for male and female relations. Here, where there is no grammatical distinction between the sexes, separate terms are used. It is worth remarking that the Bilqula, who have grammatical distinction of sex, distinguish between but a few of these terms. This may indicate that the separate forms have been lost by the tribes who use grammatical sex.

Shushwap.

Here we find a number of terms differing for males and females:

slā'e, great-grandparent and ancestors.
slā'a, grandfather.

—

k·ā'atza, father.

skū'ya, son {brother's / sister's} son.

smalt, children.
sqā'lua, husband.
k·a'tsk·a, elder brother.

ememtsī'tsilt, great-grandchild.
gyā'a, grandmother.
ēmts, grandchild.
gyē'eqa, mother.

stlemka'lt, daughter {brother's / sister's} daughter.

memā'us, married couple.
smae'm, wife.
k·a'k·a, elder sister.

sk·urō'rē, younger {brother. / sister.}

Terms used by Male.

ō'k·ē, brother.

lā'ua, {father's / mother's} brother.

k'ō'ya, {father's / mother's} sister.

TERMS USED BY FEMALE.

ō'k·ē, sister.

si'sa, {father's / mother's} brother. *tō'ma*, {father's / mother's} sister.

AFFINITY.

1. *Husband, viz., wife living.*

sqā'qoā, father-in-law and his brothers.
tltsitsa'k, mother-in-law and her sisters.
snektl, son-in-law.
sā'pEn, daughter-in-law.
sts'aqt, wife's brother, sister's husband.
ska'ū, husband's sister.

s'ā'tstEm, wife's sister, husband's brother.

2. *Husband, viz., wife dead.*

sk'a'lp, used for all relations by marriage after death of husband or wife.

The most important feature of this system, besides those which are similar to the Stlā'tlEmH, is the use of separate terms for 'uncle' and 'aunt' by boy and girl. From a comparison with other dialects it appears, that boys call their uncles fathers, their aunts aunts, while girls call their aunts mothers (derived from *tōm*, to suck), their uncles uncles.

Okanā'k·ēn.

Great-grandfather, *tat'ō'pa*, great-grandchild.

sqa'qpa, father's father.
k'i'koa, mother's father.
k·ā'k·ana, father's mother.
stEmtē'ma, mother's mother.

sEn'ē'mat, grandchild.

sk·sē, son.
st'Ekiē'lElt, daughter.
sqē'lui, husband.
nā'qnuq, wife.

nEqEnuquē'us, married couple.

tlk·ā'k·tsa, elder brother.
tlkī'kqa, elder sister.
sī'sEntsa, younger brother.
stcEtcEō'ps, younger sister.
sm'ē'elt, father's brother.
sisī', mother's brother.
sk'ō'koi, father's sister.
swāwa'sa, mother's sister, step-mother.

stluwi'l, brother's, sister's child.

TERMS USED BY MALE.

lEē'u, father.
sk'ō'i, mother.

TERMS USED BY FEMALE.

mistm, father.
tōm, mother.

TERMS OF AFFINITY.

1. *Husband, viz., wife alive.*

sqā qa, father-in-law.
tltcītck, mother-in-law.

ntē'mtEn, {wife's / husband's} family calls {husband's / wife's} family.

stsiqt, wife's brother, sister's husband.
sēastā'm, wife's sister, brother's wife, husband's brother.

2. *Husband, viz., wife dead.*

Relationship ceases, except the one corresponding to *sēastā'm*, which is called *nEk·oi'tstEn*, deceased wife's sister, deceased brother's wife, deceased husband's brother.

This brings out very clearly the peculiar form in which the levirate prevails among this tribe.

Kalispelm.

I give the terms of relationship in this dialect, which is closely related to the Okanā'k·ēn according to Mengarini.

to'pie, ancestor.
sqaèpe, father's father.
sile', mother's father.
skusē'e, son.
k'eùs, elder brother.
sinzé, younger brother.
sm'èl̂, father's brother.
s'si'i, mother's brother.

kène', father's mother.
ch'chièz, mother's mother.
stomchèlt, daughter.
l̂ch'chschèe, elder sister.
lkak'ze, younger sister.
ka'ge, mother's sister.

TERMS USED BY MALE.

l'èu, father.

skoi, mother.
skokoi, father's sister.
sgus'mèm, sister.

tònsch, {brother's / sister's} child.

TERMS USED BY FEMALE.

mestm, father.

tòm, mother.
tikul, father's sister.
snkusigu, sister.

skusèlt, {brother's / sister's} son.
sttmch'èlt, {brother's / sister's} daughter.

In Kalispelm we find once more a separate set of terms for indirect relationship when the intermediate relation is dead:

nl̂uèstn, father's brother.
ŝluèlt, brother's child.

TERMS OF AFFINITY.

1. *Husband, viz., wife alive.*

sgàgèe, husband's, wife's father.
sgelui, husband.

l̂zèzch, husband's, wife's mother.
nògnag, wife.

segunèmt, {wife's / husband's} parents call {husband's / wife's} parents.

znèchlgu, son-in-law.
szèscht, sister's husband.

zèpn, daughter-in-law.

sestèm, sister's husband, brother's wife.

2. *Husband, viz., wife dead.*

s'chēlp, daughter-in-law.

nhoi'ztn, sister's husband, brother's wife.

COMPARATIVE VOCABULARY OF EIGHTEEN LANGUAGES SPOKEN IN BRITISH COLUMBIA.

[The following vocabularies comprise mainly the well-known list of words selected by Gallatin for his great work, the 'Synopsis of the Indian Tribes' (published in 1836), which may be said to have laid the foundation of American ethnology. The list was necessarily adopted, for the purpose of comparison, ten years later, in the Report of the Wilkes Exploring Expedition on the Tribes of Oregon, and subsequently, for the same object, by other investigators, including such eminent authorities as Messrs. Gibbs, Dall, and Powers, of the U.S. Bureau of Ethnology, and

Drs. Tolmie and Dawson, of Canada. With some obvious defects, due to Gallatin's imperfect materials, it has the cardinal merit of including all those groups of words which are specially serviceable in tracing the affiliation of languages, viz., the primary terms of kinship, the names of the parts of the body, and of the most common natural objects, the personal pronouns, and the numerals. In practice American ethnologists have found Gallatin's vocabulary of very great scientific usefulness. They have been able, mainly by its aid, to accomplish already, in great part, the difficult work of classifying the numerous tribes and languages of North America and bringing the ethnology and archæology of that region out of utter chaos into some hopeful order. The following vocabularies, which have been gathered with much care, will, it may be hoped—taken in connection with the grammatical outlines given in this and the preceding reports—serve materially to further that important work as well as to elucidate the division into linguistic stocks and dialects presented in the map accompanying this report.—H. H.]

The dialects of the Athapascan (or Tinneh) languages are not contained in the list. It would have been desirable to add vocabularies of the Kaigani dialect of the Haida, of the Nasqa dialect of the Tsimshian, and of the Lower Kutonaqa, in order to give a complete review of all the distinct dialects of this group of languages. There are slight differences between the dialects of various tribes in each group which, however, cannot be included in this brief review, as they are merely provincialisms which do not hinder communication between the tribes. The dialects of the various stocks, particularly those of the Salishan stock, are arranged in groups according to their affiliations.

Stock	Dialect	Man		Woman	
		Independent	In Compounds	Independent	In Compounds
Tlingit	1 Stikeen	k·a, tlingit	—	cā′wat	—
Haida	2 Skidegate	ga, ē′tlinga	—	dj'a	—
Tsimshian	3 Tsimshian	iō′ot	—	banā′aq	—
Kwakiutl-Nootka	4 Hēiltsuk· 5 Kwakiutl	wē′sEm bEguā′num	bEgu— —	g·'anE′m tsEtā′q	kyay-,-ak·sEm kyay-,-k·as
	6 Nootka. Ts'ēciath	tcE′kup	—ath	tlō′tsma	—ak·sap
Salish	7 Bilqula	tl'umsta′ ivi′lkH	—	Hnac	—
	8 Çatlōltq 9 PEntlatc 10 Siciatl 11 Snanaimuq 12 Sk·qōmic 13 LkuñgEn	k·ai′miq cuva′ç sk·a′lmiq suē′k·a suē′k·a suē′k·a	— — — — — —	sātltq slā′naē slā′naē stlā′nē stlā′naē stlā′nē	— — — — — —
	14 Ntlakyapamuq 15 StlatlumH	sk·ā′yuq sk·ā′yuq	— —	cEmū′tlatc ciā′k·tcE	— —
	16 SEQuapmuQ	sk·ā′lemuq	—	no′qonuq	—
	17 Okana′k·ēn	sk·EltEmē′Q	—	tkitlEmē′luq coll., cmamEē′m	— —
Kutonaqa	18 Columbia Lakes	ti′tk·at	—	pā′tlki	—

Stock	Dialect	Boy	Girl	Infant
Tlingit	1 Stikeen	g·at'a'	cātk'	g·at'a'gE'tskō [6] (male) cātk'gE'tskō [6] (female)
Haida	2 Skidegate	gyit	—	g·ā'qa
Tsimshian	3 Tsimshian	wōmtlk	tlku hanā'aq	gyinē'es (male) wok·'ā'uts [7] (female)
Kwakiutl-Nootka	4 Hēiltsuk·	qāpqō'	g·'anE'mō	qEnū'q'ō
	5 Kwakiutl	bā'bākum [1]	kyayā'lam [4]	wī'sa
	6 Nootka. Ts'ēciath	mēi'tlk·ats	hā'kuatl	nā'iak·ak·
Salish	7 Bilqula	ivilivi'lkH [1]	HiHna'c [4]	—
	8 Çatlōltq	tcō'i	sā'atlq [4]	qē'ep, [8] tcī'tciat
	9 PEntlatc	stau'qoatl	slā'atlnaē [4]	tcitctcuwā'a
	10 Siciatl	mē'maan [2]	slā'atlnaē [4]	—
	11 Snanaimuq	suēk·ā'tl [3]	slEniā'ltl [5]	k·ā'ela [9] (male) k·ā'k·ela [9] (female)
	12 Sk·qōmic	suē'k·aōtl [3]	slEniā'ltl, k·'ā'maē	sk·ā'k·el
	13 LkuñgEn	suē'k·alatl [3]	slEntcā'latl [5]	k·āk·
	14 Ntlakyapamuq	tūō't	clā'nats	skūkumemē't
	15 StlatlumH	sk·E'k·Eyuq [1]	c'yē'ik·tca [4]	sk'ūk'mēt
	16 SEQuapmuQ	tūwē'ut	Qā'utEm	skuimā'melt
	17 Okana'k·ēn	tEtuwē't	Qē'QōtEm	skukui'mElt, coll., sītsEm'ā'la
Kutonaqa	18 Columbia Lakes	stahā'tl	ō'tē	tlkā'mō

[1] = little man. [2] = child. [3] = young man.
[4] = diminutive. [5] = young woman. [6] = little boy, girl.
[7] = without labret. [8] = cradle (Kwakiutl). [9] = weak.

Father	Mother	Husband	Wife	Child
īc	atlī'	k·a	cā'wat	g·at'a'
kuñ (said by male) qāt (said by female)	āō	tlāl	dj'a	gyīt
nEguā'at ā'bō (addressed)	nâ'E	naks	naks	tlkuâ'mElk
āu'mp (stem: awa-)	abō'uk āt (addresssed)	tlā'unEm	g·'anE'm	qō'nok collec., gyinā'nEm
āu'mp (stem: awa-) āts (addressed)	abE'mp āt (addressed)	tlā'unEm	g·'anE'm	gō'nok collec., gyinā'nEm
nuwē'k·sō nō'wē (addressed)	nuum'ē'k·sō ō'mē (addressed)	tcE'kup	tlō'tsma	ta'na
mān	ctān	k·tEmts	Hnac	mE'na; k·ē'k·tē
mān	tān; nikH(addressed)	gyā'k·as	sātltq	mā'ana
māa	tā'a	cuwā'k·aç	tcuwa'c	mE'na
mān	tān	nuwā'k·aç	iā'k·soo	mē'man
mä'n	tä'n	stâ'las	tsä'q	stlē'tlēk·atl
mā'ma	tci'cia	tcuwa'c	tcuwa'c	mEn
mān	tan	suē'k·a	stâ'lEs	tlētlk·ē'n nE'ñEnEñga
sk·ā'tsa pāp (addressed)	ski'Hetsa, gī'ka	sqai'ōwē	cEm'ā'm	sku'za
sk·ā'tza	skēqedā'a	k'·tāmtc nēu (addressed)	cEm'ā'm nēu (addressed)	skōzā'a coll., sku'kuza
k·ā'atsa	gyē'eqa	sqā'lua	smāE'm	smalt
lEē'u (said by male) mistm (said by female)	sk'ō'i (said by male) tōm (said by female)	sqē'lui	nā'qnuq	sk·sē, son st'Emkiē'lElt, daughter
tE'tō (said by male) sō (said by female)	mā	ti'tk·at	pā'tlki	tlkā'mō

Stock	Dialect	Elder brother	Younger brother	Indian
Tlingit	1 Stikeen	unu'q	kik'	tlingit
Haida	2 Skidegate	guā'i	dā'orEn	qā'eda
Tsimshian	3 Tsimshian	wegy (said by male)	tlEmktē' (said by female)	—
Kwakiutl-Nootka	4 Hēiltsuk· 5 Kwakiutl	nō'la ; gyī'i (addressed) nō'la	ts'ā'ea ; wīs (addressed) ts'ā'ea ; wīs (addressed)	bā'q'um bā'q'um
	6 Nootka. Ts'ēciath	tai'iē	k·atlā'tck·	kōE's
Salish	7 Bilqula	k·oa'lm	ā'qē	—
	8 Çatlōltq 9 PEntlatc 10 Siciatl 11 Snanaimuq 12 Sk·qōmic 13 LkuñgEn	nō'utl [1] tlē'wēt sEtlā'atEn, nō'utl [1] sEtlā'ētEn — cā'itl	k·ē'eq k·ē'eq k·ē'eq ; k·atē'e sk·ä'ek· sk·āk· sā'itcEn	— sk·ā'lōmiQ Qu'lmuQ Quō'lmiQ stE'lmiQ quē'lmiQ
	14 Ntlakyapamuq 15 StlatlumH	k·atck· k·Ek·tcik [2]	ci'ntci cick·'oa'dz	sk·ā'iuq ō'QuilmiQ
	16 SEQuapmuQ	k·a'tsk·a	skurō'rē	—
	17 Okana'k·ēn	tlk·ā'k·tsa [3]	sī'sEntsa [4]	sk·ēlQ
Kŭtonaqa	18 Columbia Lakes	tāt	tsā	tsEn aqtsemā'-kinik

[1] Borrowed from Kwakiutl.
[2] k·E'qk·eq, elder sister.
[3] tlkikqa, elder sister.
[4] stcEtcEō'ps, younger sister.

Stock	Dialect	Forehead		Ear	
		Independent	In compounds	Independent	In compounds
Tlingit	1 Stikeen	kāk'	—	gūk	—
Haida	2 Skidegate	k·ul	—	gyū	—
Tsimshian	3 Tsimshian	wâpq	—	mō	—
Kwakiutl-Nootka	4 Hēiltsuk· 5 Kwakiutl	tEk·ē'ioa ō'kwiwaē	—ē'ioa —aoē	b'Esbē'yō [1] b'E'sbaya	—atoa —atoē
	6 Nootka. Ts'ēciath	imits'ā't'a	—	pa'p'ē	—i'mtl
Salish	7 Bilqula	ī'lōma	—	ta'nkHta	—alsikyān
	8 Çatlōltq 9 PEntlatc 10 Siciatl 11 Snanaimuq 12 Sk·qōmic 13 LkuñgEn	ē'itcsEn sik·tsē'n E'ltctEn sk·'o'mals st'ō'kyus k·'ō'muqs	— — — — — —	k·oā'anā squē'na k·ulā'na k·'o'nEn k·'o'lān k·'o'lEn	— — — — — —än
	14 Ntlakyapamuq 15 StlatlumH	— a'lkēnus	— —kēnus	tl'a'nē tl'E'na	— —çana
	16 SEQuapmuQ	tk'amē'sHin	—isHen	tl'ā'na	—ana
	17 Okana'k·ēn	k'amē'lsQEn	—ēsQEn	t'ē'na	—ēna
Kutonaqa	18 Columbia Lakes	aqking·ā'tl	—	aqg·ō'k·oat	—

[1] p'Espē'yō ?

People		Head		Hair		Face	
Independen	In compounds	Independent	In compounds	Independent	In compounds	Independent	In compounds
tlingit	—	ca	—	caqā'wu [2]	—	rE	—
qā'ēdqa	—	k·ā'tsē	—	k·'āitl	—	qañ	—
gyit	—	tEmg·ā'us	—	g·ā'us	—	ts'al	—
— —	—ēnoq,-itq —ēnoq	hai'Htē hā'iHtē	—k·ēa —k·ēa	sā'ia sā'ia	hap— hap—	k·ōk·ōmē' k·ōk·omē'	—Emē —Emē
ōath	—ath	t'o'qts'ite	—	ha'ps'iup	hap—	hitlōtl	—utl
sia	—mQ	tEna'q	—ēaq	mE'lHk·oa	—	mō'sa	—ōs
k·ai'miQ — yā'ya [1] 'ā'yits [1] dā'i [1] cā'dja [1]	— — — — — —	mōō'ç sqiō's mōō's sqā'yis smōō's s'â'sEs	— — — — — —ēk·	mā'k·ēn sqik·ē'n smā'k·ēn cä'yitEn sk·'ōmā'i sī'atEn	— — — — — —	mōō'ç sQmō'sten mōō's ç'â'çEs s'ā'tsōs s'â'sEs	—ōs — — — — —ōs
— —	— —	k·'u'mk·an k·'ō'mk·En	— —uk	sky'a'pkan mā'k·ēn	— —	sktlūc ck'utlō's	— —ōc
'E'lmuq	—muQ	sk'a'pk·En	—k'ēn	k·ā'utEn	—	sk'tlōs	—ōs
Enak·sē'luq	—	tsā'ciak·En	—ā'yak·En	k·apk·ē'ntEn	—	sk'tlōs	—ōs
qtsemā'kinik	—	aqktlām	—	aqg·ōk·ōtlā'm	—	—	—

[1] Relatives. [2] =head hair.

Eye		Nose		Mouth		Tongue	
Independent	In compounds	Independent	In compounds	Independent	In compounds	Independent	In compounds
āk·	—	tlō	—	k·'a	—	tl'ōt	—
'ñgē	—	kun	—	qē'tl'ē	—	t'a'ñgEl	—
al'E'l	—	ds'aq	—	kutl'ā'q	—	dū'Ela	—
ks 'yak·s	—qstoa —qstoē	Hmāk Hi'nts'as	—itlpa —itlpa	sums sums	—qtaē —qstaē	gyi'lEm gyi'lEm	— —
'sē	—ksutl	ni'ts'a	—ahta [1]	yi'neksutl	—aksutl	tc'up	—
·lōks	—ōtla'k'ōs	mā'qsē	—alk·s	tsū'tsa	—ōts	tī'Htsa	—lē'its
'wūm lō'm lō'm 'lEm lō'm 'lEm	— — — — — —	mE'k·sEn mE'k·sEn mE'k·sEn mE'k·sEn mE'k·sEn nE'k·sEn	— — — — — —Ek·sEn	çō'çin çō'çin çō'sin çâ'sin tsō'tsEn sâ'sEn	— — — — — —	tē'qçuatl tē'qçuatl tē'qçuatl tē'qçatl mEk·a'lqtsatl tē'qsEtl	— — — — — —
ctl'u'ctEn 'ctEn	— —aluc	spsak·s sp'E'sEk·s	— —alEk·s	splū'tcin tcū'tcin	— —itc	tā'tla tā'tla	— —
'stEn	—	spsak·s	—ak·s	splū'tcin	—tsin	tiquā'atsk'	—
(nuk)tlō'stEn	—	spsāk·s	—ak·s	spElē'mtsEn	—a'usk·En	tēQtc	—
·ā'k·tlītl	—	aqk·uk·tsa'tla	—	aqk'atlu'ma	—	watlōna'k'	—

[1] =point.

Stock	Dialect	Tooth: Independent	Tooth: In compounds	Beard	Neck: Independent	Neck: In compounds
Tlingit	1 Stikeen	ōq	—	k·atatsā'yē	dlētū'q	—
Haida	2 Skidegate	dz'ᴇñ	—	sk·'ē'ōrē	qil	—
Tsimshian	3 Tsimshian	ua'n	—	ēmq	t'ᴇmlā'nē	—
Kwakiutl-Nootka	4 Hēiltsuk·	gyiky	—ʜsia	hāpeʜsiā' [1]	g·'ōg·'ō'ne	—
	5 Kwakiutl	gyiky	—ʜwē	hāpa'qstēya [2]	g·'ōg·'ō'n	—
	6 Nootka. Ts'ēciath	tcī'tcitci	—	ha'paksum [2]	ts'ē'kumᴇts	—
Salish	7 Bilqula	ī'tsa	—qa'lits	sk·obō'ts	asa'lqē	—
	8 Çatlōltq	dji'nis	—	k·ō'pōçᴇn	sā'itlatl	—
	9 Pᴇntlatc	yi'nis	—	k·ō'pōçᴇn	sik·tlsē'e	—
	10 Siciatl	yi'nis	—	k·opō'oçin	s'a'ltlatl	—
	11 Snanaimuq	ye'nas	—	k·uinē'içᴇn	a'ltlatl	—
	12 Sk·qōmic	yi'nī's	—	sk·oā'ns	k·ᴇ'nᴇk·	—
	13 Lkuñgᴇn	tsᴇ'nᴇs	—	k·oai'nisen	qoā'ñgan	—
	14 Ntlakyapamuq	qiā'q	—	cuptcī'n	sk·'amē'tᴇn	—
	15 Stlatlumʜ	rā'itcmᴇn	—	cwuptc	k·ā'k·anāa	—atlk·uitl
	16 Sᴇquapmuq	qᴇla'q	—	suptsē'n	qkuya'pstᴇn	—yapstᴇn
	17 Okana'k·ēn	aai'tᴇmᴇn	—	cōptcē'n	kᴇspā'n	—
Kutonaqa	18 Columbia Lakes	aqk·u'nan	—	aqkuk·tla'qa	aqgō'ugak	—

[1] =tooth hair. [2] =mouth hair.

Stock	Dialect	Nail	Body: Independent	Body: In compounds	Chest: Independent	Chest: In compounds
Tlingit	1 Stikeen	qak·	—	—	ʜētk·a	—
Haida	2 Skidegate	sl'g'u'n	tēā'nē	—	k·an	—
Tsimshian	3 Tsimshian	tlᴇqs	—	—	k·ā'yek·	—
Kwakiutl-Nootka	4 Hēiltsuk·	ts'ᴇ'mts'ᴇmskyanē	ōk'ona'	—na	tqk·'āpoa'	—poa
	5 Kwakiutl	ts'ᴇ'mts'ᴇm	ōk'ona'	—na	ōpoē	—poē
	6 Nootka. Ts'ēciath	tc'a'tltc'a	—	—p'a	āma'shotl	—shotl
Salish	7 Bilqula	sk·'atʜē'qoak	s'ō'nqta	—ālos	sk·ma	—alōs
	8 Çatlōltq	k·ap'adjēk·ō'dja	gī'ēus	—	aiē'nas	—
	9 Pᴇntlatc	qōlē'k·ōya	wē'yus	—	sēk·ēnā's	—
	10 Siciatl	k·ap'ē'k·ōyam	—	—	alē'nas	—
	11 Snanaimuq	k·qoā'lautsis	—	—	s'ē'les	—
	12 Sk·qōmic	k·qōyēk·ō'yatc	—	—	s'ē'lēnes	—ēnᴇs
	13 Lkuñgᴇn	tcca'lses	tcā'lēitᴇn	—ēkus	tsñgatl	—ēnᴇs
	14 Ntlakyapamuq	k'uqk·ē'nkqst	—	—	tlikmo'qtck	—
	15 Stlatlumʜ	k·qk·ēnakāa	mᴇā'tc	—	tā'qoatc	—qoatc
	16 Sᴇquapmuq	k'oqkoē'nek·st	suwa'nuq	—	tkmā'lis	—ālis
	17 Okana'k·ēn	k·uqk·ēnkʜst	sk·ētlk'	—	sky'iltkamē'les	skyilt—ē'les
Kutonaqa	18 Columbia Lakes	aqgō'ukp	—	—	aqguwī'tᴇgak	—

Arm		Hand		Finger	Thumb
Independent	In compounds	Independent	In compounds		
djin	—	djin	—	tl'ēk·	gō'uc
ʜi	—	slā'ē	—	slk·'a'ñgē	sli'k'usī
an'o'n	—	an'o'n	—	—	mâs
oqsiap'ē' ā'yasō	—siap'ē' —	hāiā'sō k·oā'k·oaqtsana	—skyanē —tsana	k·oā'k·oaqskyanē k·oā'k·oaqtsāne	k·ō'na k·ō'ma
āaphi'mtl	—yemitl	kwi'kuniksō	—nuk	ts'āts'atlak·nuku'mE	lEhkumE'ts
sū'qya	—	uts'ū'tlikak	—	sk·utE'lqsek	k·ō'na [1]
tciā'ias sik·elaqā'n tciā'las t'ā'lō nāqtc t'ā'lō	— — — — — —	kutētsinō'dja sik·enatcō'ya kut'ecinō'ya tcä'lic — sāls	—ōdja —ōya —ōya —autsis —autsis —āsEs	tcā'las qoā'ōk·odja nik·ō'yats qōlik·ō'ya snE'qtsEs —	tlāqēk·ō'dja tlatlqē'qk·ōya tlaqak·ō'ya sEntlā'lautsis [2] asē'utlEk·ō'yatc [2] sltlā'leses [2]
kē'iq sqōrā'qEn	— n—aqan	— skua'kst	— —akāa	lEqkst qola'ka	skiaqē'nkst tsk·ō'lak·a, skil'ā'ka
kalʜ	—	—	—k·st	lEqli'qk·st	sʜatEmqa'k·st [2]
kilʜ	—aqan	kilʜ	—kʜst	kilʜ	stōmkʜst
aqktlā'at	—	aqgē'i	—	aqgEtsg·ā	d'utsā'k

[1] Borrowed from Kwakiutl. [2] =hand's elder brother.

Belly		Female breasts	Leg		Foot		Toes
Independent	In compounds		Independent	In compounds	Independent	In compounds	
ūra'	—	tla	k·'ōs	—	k·'ōs	—	k·'ōs tl'ēk·
lEl	—	k·an	gy'atl	—	st'a'ē	—	st'a k·'a'ñgē
En	—	—	sī	—	sī	—	—
ky'ē ā'ikyē	— —	ts'ām [1] ts'ām [1]	asā'nōtsEqtlē ōnutsE'qstē	— —	kō'kuē gyū'koiū	—sītsē —sītsē	k·oā'k·oasitse k·oā'k·oasītsē
ā'atca	—nak·ē	i'nEma	aptsita'k·tlē [2]	—	tli'ctlin	—ti'mE	ts'āts'atlak·ti'mE
'ul	us—ōtsitl	tōms [1]	Independent: ī'ʜa			In compounds: —	skutlqsEtl
oā'oa ulā' 'ulā' 'oa'la 'ul 'ula'	— — — — — —k·ēn	tsu'mtEn sk·Emâ'o [1] k·Emō'o [1] sk·ma [1] stElk·oē'm [1] sk·ma [1]	dji'cin ā'utcin yi'cin sqe'na sqan sqe'na			—cin —cin — —cin —cin —aitcitc [3] —sEn [4]	qoā'oadjicin qulēk·ō'cin — snā'qcin nēqk·ō'icin —
— lē'n	— —	— sk·Eā'm	sk·'aqt sk·'aqt			—qEn —qEn	lEqqEn nEqō'liqEn
ula'nk	—ank	sk·aā'm	sk·'oa'qt			—qEn	lēqqEn
ultsenē'nk	—ēnk	sk·ēē'ms [1]	sts'ō'qan			—(ōst)qEn	stō'mqEn
kōwu'm	—	—	a'qsak·	—	aqktī'k	—	aqkink'a'tlik

[1] From to suck. [2] Outer side of thigh. [3] Leg. [4] Foot.

Stock	Dialect	Bone	Heart	Blood	Town	Chief
Tlingit	1 Stikeen	s'āk·	tēk·	ci	āa	ank·ā'ō
Haida	2 Skidegate	sk·ō'tsē	tēk'ō'yo	gā·'i	lā'na	ētlqaqagida [1]
Tsimshian	3 Tsimshian	sâ'yup	k·â'ot	itlē'	k·'a'lds'ap	sEm'â'yit
Kwakiutl-Nootka	4 Hēiltsuk·	qāk·	wa'stEma	a'lg'um	gōk'	hē'mas
	5 Kwakiutl	qāk·	no'kiē	alg'	gyōk'	gyī'k·amē [2]
	6 Nootka.Ts'ēciath	ha'mūt	t'ī'tcma	he'smis	ma'utl	ha'utl, tcā'mata
Salish	7 Bilqula	tsāp	sElkH	sīH	apsō'tl	stalto'mH
	8 Çatlōltq	qau'cin	tlā'qēgan	k·uē'tl	*vacat*	hē'gyus
	9 PEntlatc	ciā'ō	stE'mtEn	k·ō'ētl	*vacat*	hē'wus
	10 Siciatl	—	tlā'qēwan	sk·uē'tl	*vacat*	hē'wus
	11 Snanaimuq	ctçām	tsä'la	çō'çin	*vacat*	siä'm
	12 Sk·qōmic	cā'o	ts'ā'lē	stā'tsiēm	*vacat*	siā'm
	13 LkuñgEn	sts'âm	tlHkoa'ñgal	cäctcin	*vacat*	siā'm
	14 Ntlakyapamuq	k·'ōk·ō'otl	sQuo'qōk	pEti'la	*vacat*	kū'kpi [3]
	15 StlatlumH	k·'ōk·'ō'itl	sQua'kuk	pti'lāa	tcītcītq [1]	kō'kpi
	16 SEQuapmuQ	k·uk·qō'otl	p'ō'smEn	mētky'iē'e	tcītcī'tQ [1]	kō'kpi
	17 Okana'k·ēn	sts'ēm	cpōō's	mEtlkē'a	tcītcī'tQ [1]	hīlmē'Qum
Kutonaqa	18 Columbia Lakes	mā'kE	aqkitlwē'	wa'nmō	aqkEktlō [1]	nasō'kē'

[1] = houses. [2] = the highest chief. [3] kō'kpi, Bilqula = grandfather.

Stock	Dialect	Axe	Knife	Canoe: Independent	Canoe: In Compounds
Tlingit	1 Stikeen	cEnqoā'ri	tlta	yā'uk	—
Haida	2 Skidegate	kyētldsā'ō	sqā'u	tlō'u	—
Tsimshian	3 Tsimshian	dahE'TEs	hatlēbī'esk	qsâ	—
Kwakiutl-Nootka	4 Hēiltsuk·	k'ō'kunakula	qtai'ō	gyi'l'oa	—
	5 Kwakiutl	sōp'a'yō	ky'auwai'ō	gyā'lo [2]	—qs
	6 Nootka.Ts'ēciath	hi'siyek·	a'kyek·	tcā'pats	—ahs
Salish	7 Bilqula	tqta	k·tla	tlā'laз	—
	8 Çatlō'tq	s'ōpai'ū [1]	tctā'ēten	nE'quitl	—
	9 PEntlatc	s'ōpai'ū [1]	—	nE'quitl	—
	10 Siciatl	sō'paius [1]	skuē'tctEn	nEquī'tl	—
	11 Snanaimuq	sk·k·um	tlā'tstEn	snE'quitl	—
	12 Sk·qōmic	k·k·u'mEn	tlā'atctEn	snE'quitl	—
	13 LkuñgEn	k·k·um	cī'pan	snE'quitl	—Qutl
	14 Ntlakyapamuq	k·'ō'isk·an	cElī's	tskaā'utl	—
	15 StlatlumH	k·'oē'ck·ēn, tlamē'n	Qwī'k'tEn	kHlats	—
	16 SEQuapmuQ	tlEmē'n	sk'umē'	astk·ā'utl	—āutl
	17 Okana'k·ēn	QElEmī'n	nē'k'amEn	stā'tlEm	—
Kutonaqa	18 Columbia Lakes	aqkatlē'etis	aqktsā'mōtl	yak·tsō'mītl	—

[1] Borrowed from Kwakiutl. [2] Obsolete, generally called qua'k'una.

Warrior	Friend	House		Kettle	Bow	Arrow
		Independent	In Compounds			
g·āns'atē' [1]	qonē'	hit	—	ōq'akāgantE'	sEk·s	tcunē't
gutl'ī'sta	quē'	na	—	k·ā-ētla	tlk·ēt	ts'ī'talEñ
—	nEsē'bansk	wālp	—	—	haukta'k·	hāuā'l
— winaē'noq	— nEmō'k·	gōk' gyōk'	—ītl —ītl	hanHtlāla [3] hanHtlāla [3]	tlkuē's tlkuē's	hā'ntlEm hā'ntlEm
mā'ptaqsath	hōwā'tEn	mahtē'	—	sūtl	mō'statē	ts'ē'hatē
—	k·amā'its	sōtl	—	qanisā'tls [4]	pō'tstEn	tsHnē'mta
— — — stâ'mic suē'k·a [2] qElqē'lEtl	— tcā'lac — siä'ia — —	tlEms, ā'ya tlEms tlEm, ē'luwEm lä'lEm lām ā'lEñ	— — — — — —ōtq	hā'niHtlala [4] hā'niHtlala [4] k·u'lstan ck·oa'ls nk·ō'isten ck·uk·u'ls	haihē' k·tsē'itc haiā'itEn tā'qoats tō'qoats cq'umā'tEn	tlōk· tats'ō'mēn tlōk· skulä'c sEk'Ela'c tsEmä'n
— nEk'cā'nEk	— —	tcitQ tsī'tuQ	— —	qaiē'k·a tck·ō'ctEn	tckuī'nEk to'qoatc	skuī' k·'cma'lite
—	—	tsītQ	—	tlkāp	tckuī'nik	skuī'l
—	—	tcītQ	—	tlkāp	tckuē'nik	tck·ē'lEn
guwanak·anā'niau'ē	sūwō'	aqgitlā'	—	yi'tskī	t'ā'ō	aqk·uqumatlē'et

[1] =war master. [2] =man. [3] =kettle on fire. [4] Borrowed from Kwakiutl.

Moccasins	Pipe	Tobacco	Sky	Sun	Moon	Star
tītl	ts'ēk·dakēt	g·āntc	akawaqa'ts	gān	dīs	k·utaq'arenaha'
st'ätlk'u'nkyē	g·ā'ēu dā'o	gul	k·ōyēk·a rān	dzilg·oē'	k·'uñ	k'ēitsā'ō
ts'â'oqs	aqpēyā'n	wundâ'	ts'Em laqa'	gyā'm'uk	gyā'm'uk	p'iā'ls
k·ē'naq t'ēpa'yō	wā'qatsē [3] wā'q'atsē [3]	tlā'uk· tlā'uk·	lEwa' lō'ua	tl'ēHsioala tlē'sEla	nō'si mū'k'ola	t'ō'toa t'ō'toa
tlEk·'e'cinE [1]	ku'csEts	—	hinā'yitl	nās	hūpa'tl	tat'ō's
k·ēnq	nusu'k·pta	tl'ā'uk·	—	sōnH	tl'ōkH	meHmē'kHtl
tlE'k·cin tlE'k·cin tlE'k·cin k·tlā'itcin k·tlē'isin k·tlē'itcin	wā'q'atsē [4] wā'q'atsEn [4] p'ā'tlEmā'lē cpEtlEmā'lak· ntsk·ō'tstEn pōtlEmā'la	ā'wak· ā'wak· spā'tlEn spā'ltEn spō'tlEn —	kuā'yanō skuā'yil skuā'yil skuā'yil skuā'yil skoā'tcil	tE'gyim st'ē'qēm stsōk· ciā'k·um tlk·ā'itc sk·ok·o'l	tE'gyim spē'los ciā'lsiatl tlk·älts tlk·ā'itc tlk·altc	kuō'sEn kuō'sil kuō'sen koā'sEn kō'sen kâ'sEn
citltsō'wē ci'tltsē	ntsak·ō'ētctEn ts'k·ō'otctEn	cEmē'n'Eq cmā'niH	stlēk·t stl'ēk·t	sk'ō'koac snu'k·um	mā'qEtEn tl'ā'nāmtEn	nkokū'cEN kakō'cinEt
siltsuō'e [2]	tsk·ō'otEn	smanQ	stlēk·t	skwa'k'as	mā'qē	skukō'sent
k·āaqā'n	sEnmā'nuqtEn	smā'n'uQ	st'Eky'Emā'sqk·	qēā'tlnuq	qēā'tlnuq	sQukō'sent
tlān	kōs	yā'k·'ēt	aqkitlmī'yit	natā'nik	natā'nik	aqkitlnōhō's

[1] Borrowed from Snanaimuq. [2] =common shoes. [3] =smoke receptacle. [4] Borrowed from Kwakiutl.

Stock	Dialect	Day	Night	Morning	Evening
Tlingit	1 Stikeen	yigEri′	tāt	ts'u tāt	qā′na
Haida	2 Skidegate	sEn	gālqua	sEn aē′QEn	sEn Hī
Tsimshian	3 Tsimshian	sa	hō′opEn	k·antlak·	skī′yetlak·s
Kwakiutl-Nootka	4 Hēiltsuk· 5 Kwakiutl	nā′la nā′la	nēkk k·ā′nūtl	k'oa′k·oai′la nā′H'it	— —
	6 Nootka.Ts'ēciath	nās	a't'hāi	kō′atl	tō′pcitl
Salish	7 Bilqula	kH'i′mtam	ī′Hentl	i′naq	entl
	8 Çatlōltq 9 PEntlatc 10 Siciatl 11 Snanaimuq 12 Sk·qōmic	ts'ōk· koā′yil skuā′yil skuā′yil skuā′yil	nāt nāt — snēt snāt	kū′i nā′tatl skuē′kuē nā′tētl nātl	nā′anat Emsī′yi snāt Qunä′nt nā′nanat
	13 LkuñgEn	skuā′tcil	nät	kutcī′l	tä′ñgEn
	14 Ntlakyapamuq 15 StlatlumH	cī′tlk·'at sk·'ē′it	cī′tict cītst	nūwE′nuwEn nā′natQ	tsōō′s rāp
	16 SEQuapmuQ	sitk·t	sī′tist	Qua′nūn	rāp
	17 Okana′k·ēn	sqElqā′l	cEnūkoā′ats	tlētlkūkoā′st	ky'Elā′up
Kutonaqa	18 Columbia Lakes	giū′kwēyit	tsitlnū′yit	wu′tlnām	watlgoā′it

Stock	Dialect	Rain	Snow	Fire	
				Independent	In Compounds
Tlingit	1 Stikeen	sē′u	dlēt	k·'ān	—
Haida	2 Skidegate	dāl	d'ärā′u	—	—
Tsimshian	3 Tsimshian	wās	mā′dEm	lak	—
Kwakiutl-Nootka	4 Hēiltsuk· 5 Kwakiutl	iō′koa iō′koa	na′ē[1] nā′ē[1]	QuiʹltEla Hē′k·ala	— —
	6 Nootka.Ts'ēciath	mī′tla	kwi′s	inik·	—
Salish	7 Bilqula	atlvu′lat	kH 'ai	nē′iq	—
	8 Çatlōltq 9 PEntlatc 10 Siciatl 11 Snanaimuq 12 Sk·qōmic 13 LkuñgEn	tciē′tl smā′yelam tciē′tl slE′mEq slumq tlEmq	k·ō′mai aq sk·ō′maē mā′k·ä mā′k·a ñgā′k·ē	qoā′uitq cpāts tcitcī′em hai′uk· yē′iōtl ctcik·ō′esā	— — — — —tsEp —
	14 Ntlakyapamuq 15 StlatlumH	tEktl ckwīc	cūu′qt mā′k·aa	duktik' ru′lEp	— —ik'p
	16 SEQuapmuQ	skla′kstEm	uō′qt	tē′ik'	—
	17 Okana′k·ēn	ck·'ēt	sEmē′k't	tcū′quap	—
Kutonaqa	18 Columbia Lakes	guwatlōk·uk·u′k·ut	a′qktlō	aqkink·ō′k·ō	—

[1] It is snowing, kuē′sa.

Spring	Summer	Autumn	Winter	Wind	Thunder	Lightning
—	k·utā'n	—	—	ky'ētlca'	Hētl	Hētl ē'gu
k·'in rE'da	k·'in	—	sEñgā'rat	tadzā'ō	hē'lañ	sqitg·ā'uldañ
—	sōnt	ksō'ot	k'âtl	päsk	kalEplē'em laqa'	ts'ā'mti
wēā'gyīoa —	hā'inq hēianq	— —	tsawi'nq tsawa'nq	iâ'la iâ'la	kū'niHua kū'niHua	— tlEnē'quit
tla'k·citl [1]	tlōp'ē'itc [2]	aiē'tc	tsōiē'tc [3]	wē'k·sē	t'ētsk·i'nE	tlēhtlē'ha
—	āmtl	nuskHlqutsts	nuskHluts	asō'kH	nilqī'm	sQuQu'm
tlē'itcus tEmtlqmōs — cicā'wa ēkumē koā'koasi	tlEkō'ē tEm'ē'yus — k·'oē'les tEtEmiē'is	— — — misâ'tets —	çō'titc tEmqē'tlēm — susâ'tits tEmt'ēq	pō'qam pahā'm pō'ham stsE'qum spEhē'm	qutk·'umē'ns walō'qum kutstciē'm sQuQoā'as ēnēniā'qaan	sasā'gyim lā'lmEn sō'usōwum qEqE'nak·t tqā'ēutsē, ēnēniā'-qan
—	k·'oē'les	—	—	spquE'la	sQuQoā'as	k·'unE'la
— nRō'tsk·āa	cEnk·'oiya'nk· pēpa'ntcik	— tl'wā'litstEn	— cū'tik	cnā'ut ck'a'qEm	ki'kiaq cki'lEklEq skinEkinā'p	nmamā'am wulwulk·'ō'cEm
sk·apts	sk·a'lk·altEmQ	tlwa'lstEn	s'istk	snā'ut	skinkinā'p	sūkwa'kEmEnst
pEsk·ē'ptc	pēstcEa'k·	pēskEai'	pēsEē'stk	sEnē'ut	sEk·tsk·ā'm	cuwik'ēst
—	—	—	—	aqkō'mē	nō'ma	nō'ma

[1] = sprouting season. [2] = warm season. [3] = season when everything clean.

Water		Ice		Earth, Land		Sea	River
Independent	In Compounds	Independent	In Compounds	Independent	In Compounds		
hīn	—	t'ēk·	—	ā'nē	—	rEk·ā'k	hīn
g·andl	—	k·a'lga	—	tlga	—	tā'ñga	k·ā'ura
aks	—	dā'u	—	dsā'atsEks	—	qātla ; laq mân[1]	g·'ala aks [2]
wāa'm wap	—sta —sta	tl'ōq tl·ō'q	— —	tsqams t'E'kya	— —	tEmsH tEmsH	wa wa
tc'ā'ak	—	k·ō'uq	—	ts'a'k'umts	—	tō'p'atl	ts'ā'ak
kqla	—	skH'ilk	—	koqtlō'lem	—	sōlū't	tmH, anaqō'm
k·ā'ea s'ē'wuç s'ē'wuç k·a stāk· k·oā'a	— — — — — —	tau'ō spē'ū spē'ū spē'ū s'ō'Hen stlā lEq	— — — — — —	gi'dja mē'i tEmē'q tE'mEq tEmē'q ta'ñguq	— — — — — —	kuō'tlkō kuō'tlkō kuō'tlkō k'uā'tlkua kuō'tlk tltlā'tlsē	k·'utE'm stō'lau stâ'olō stâ'lō stāk· stâ'lō
k·ō'E k·ō	— —atkua	npā'uē ck'ē'malEtc	— —	tEmī'Q tEmē'Q	— —	— k'ōtl	k·ō'u ctcuwā'uq
—	—atkua	sQū'yint	—	tEmē'Q, tlu'k·luq	—	—	sEtā'tkua
cī'wutlk'	—itk'	sQō'int	—īkEn	tEmEqō'lau	—	—	cā't'itk'
wō'u	—	a'qgut	—	—	—	aqk·'asuk'wū'ō	aqkinmi'tuk

[1] = on the salt. [2] = ascending water.

Stock	Dialect	Lake	Valley	Mountain	Island
Tlingit	1 Stikeen	āk'	ciā'naq	ciā'	k·'āt
Haida	2 Skidegate	sū	tl'ā'dan	t'ē'is	guā'i
Tsimshian	3 Tsimshian	—	tlkut'ē'en	sqanē'ist	lEksd'a' [4]
Kwakiutl-Nootka	4 Hēiltsuk·	g'ā'us	—	g'ō'gwis	tl'ēkyā'ē
	5 Kwakiutl	ts'ā'latl [1]	—	nī'kyē [2]	makyâ'la
	6 Nootka. Ts'ēciath	a'uk'	—	nu'kyē	tca'ök
Salish	7 Bilqula	tsātl	nůt'E'l	smnt	k·enk·e'lsk
	8 Çatlōltq	sā'eatl	djuqtlā'tc	tā'k·'at [3]	ku'çais
	9 PEntlatc	sEl'ā'tl	tlEpk·ē'n	smā'nit	ckçā'as
	10 Siciatl	tslātl	tlEpk·ē'n	smānt	skuē'ktsaaç
	11 Snanaimuq	—	cqolā'k·	smänt	skçä
	12 Sk·qōmic	—	sQō'qul	smā'nēt	s'ā'ek's
	13 LkuñgEn	—	—	sñgä'nit	tltcās
	14 Ntlakyapamuq	pe'tluckum	—	sk·um	—
	15 StlatlumH	tcalā'tl	ntçitce't	sk·um	k'QI'nōEc
	16 SEQuapmuQ	—	qlâtē'kin	tsk·ōm	sū'nkum
	17 Okana'k·ēn	t'ē'k'ut	tsEnlā'ut	mEkwī'ut	kcō'nuk
Kutonaqa	18 Columbia Lakes	aqk·u'g·unuk	—	aqkōwuqtlē'et	aqg·'ā'nkemē

[1] Borrowed from Salish. [2] Borrowed from Nootka. [3] Vide stone. [4] =sitting alone.

Stock	Dialect	Wood	Leaf	Bark	Grass	Flesh, Meat
Tlingit	1 Stikeen	g·an	kag·anī'	atlaqē'	sō'uk·	dlīr
Haida	2 Skidegate	tlkyān	tleya'ñgual	k·'ō'tsē	Hil	gyēri'
Tsimshian	3 Tsimshian	—	ia'nEs	gyīmst	kEyâ'qt	ca'mi
Kwakiutl-Nootka	4 Hēiltsuk·	gyā'p'as	mēmē'eqtlāō	qk'um	ky'ē'tEm	mēa's
	5 Kwakiutl	—	paā'k·	qā'k·'um	ky'ē'tEm	Elts
	6 Nootka. Ts'ēciath	i'niksē	tla'k·ap	ts'a'k·mis	a'k·mupt	—
Salish	7 Bilqula	kumtl	k·oa'ls	īk·	—	—
	8 Çatlōltq	k·oi'q	p'ā'k·'am [1]	p'ā'ian	tlEqEm	mE'gyas
	9 PEntlatc	k·ō'iq	p'ā'k·'am [1]	tlā'k·'ot	sā'qoitl	slēk·
	10 Siciatl	sk·oiqiā'ō	p'ā'k·'am [1]	spelā'n	—	slēk·
	11 Snanaimuq	siâ'tl	ts'ā'tlam	slā'ēn	—	slēk·
	12 Sk·qōmic	yē'iōtl	ctc'ō'tla	—	sā'qoē	slēk·
	13 LkuñgEn	ctcâtl	—	—	—	slēk·
	14 Ntlakyapamuq	—	—	kEzē'	—	šmītc
	15 StlatlumH	mō'lEq	pi'tckEtl	cī'kīl	cts'E'pEz	ts'ī
	16 SEQuapmuQ	stktsō'sEm	ptsaktl	p'Elā'n	stlia'	—
	17 Okana'k·ēn	sElē'p	pātcktl	k'ēlē'luq	cōpō'lauQ	slēk·
Kutonaqa	18 Columbia Lakes	—wōk	aqku'tlatl	aqgi'tsk·atl	qā'atltsin	—

[1] Borrowed from Kwakiutl.

Salt	Stone		Iron	Forest	Tree	
	Independent	In compounds			Independent	In compounds
ētl	t'hE	—	ik·ēyē'ts	—	k·ats	—
tā'ñga g'ā'ga[1]	tlqa	—	irē'ts	tlkyān[6]	k·'ēt	—
mân	lâp	—	t'ō'otsk	—	k·an	—
tEmsH	t'ē'sEm	—a	—	koā s	lEk·oa'	—mis
tō'p'atl	t'ē'sum	—a	—	ā'tlEn[7]	tlā'qtlos	—mis
tō'pitl	mu'ksi	—a	—	—	tlā'k·aas	—mopt
sts	tqt[4]	—	—	—	stEn	—
k·'ō'tlōm	qāadjē'c	—	—	çī'tcim	djā'ia	—
k·'ō'tlōm	qīā'ls	—	—	çī'tcim	sk·ō'iQ	—
k·uō'tlōm	—	—	—	çī'tcim	sī'a	—
tl'ā'tlEm	tlā'tsa	—	—	tsâ'lak·	sk·ät	—
tl'ā'tlEm	smânt[4]	—	—	tcī'cEm	stsEk·	—atlp
tl'ā'tlEñ	stlk·â'tcēsen	—	—	tcī'tEñg	sk·aiyai'eñg	—Etltc
ts'alt (?)[2]	sQEnQ	—	—	—	ciqa'p	—
tl'ā'tlEm	k'E'tla	—	—	mElmō'lEq	cErā'ap	—
				stlikitlk'a'luk		
—	sQenQ	—asqEn	swilEwulā'lEm[5]	nEka'qt	tsEra'p	—
				stsiltsā'l		
lēsa'l[3]	Htlōt	—	wulEwulē'm	hEnstī'tsō	tcirē'p	—
gwistlā'qanē	nō'okwē	—	ni'tlgō	tsitlē'it	aqgitstlā'ēn	—

[1] =dry sea. [2] =English? [3] =French. [4] See mountain. [5] =hard thing. [6] See wood. [7] =rear of, interior of country.

Dog	Bear, Black	Bear, Grizzly	Wolf	Deer	Elk	Beaver
kyētl	ts'ēk	Qūts	g·ō'utc	k·ookā'n	tsisk[4]	ts'ikrēdē'
qa	tān	Qō'ots	g·ō'utc	g'at	tsi'cku[6]	ts'Eñ
has	ol	mEdī'ek	kyebō'	wan	siâ'n	sts'âl
ua'tsē	nan	tl'a[3]	k'usE'ls	k·a'mēla	tlaō'ls	kōlō'n[8]
ua'tsē	nan	gyi'la	atlā'nEm	k·ē'was·	tlōls	ts'ā'ō
ai'nītl	tci'mis	—	k·'ā'natla	ā'tuc	tlō'nem	a't'ō
uo'ts[1]	nān[2]	tl'a	nutsek·ō'aq	sHpā'nitl	tlâ'les[7]	kōlō'n
tsiā'anō	mē'qatl	qau'gas	tlā'acōm	k·ē'gaç[2]	k·'ē'etc	smayā'ō
ctc'ī'nō	squisE'lk·ēn	qai'uas	tattciō'lmiq[4]	sqō'icin	tsēnā'tc	t'akō'm
ctcī'nō	dji'tqun	qau'gyas	tk·'ā'ia	hâ'opet	k·e'litc	k·ō'lūt
sk·umä'i	spä'as	k'ō'yētsin	stk·'ā'ia	hâ'opet	k·ī'etc	sk·Elā'ō
sk·umā'i	mē'qatl	stlatlā'lem	tk·'ā'ia	k·iē'etc (?)	k·iē'etc	sk·Elā'ō
sk·umä'i	ctcE'tqun	k'ō'yētcin	tk·'ä'ia	smē'yis[5]	kwā'waatc	sk·Elā'ō
sk·ā'k·qa	—	—	sk·'ā'um	cmī'etc[5]	sqoia'qk·En	cEnū'ya
sk·a'qāa	mē'qatl	stlātlā'lEm	sk·'ā'uam	stl'ō'la	—	sk·Elō
sk·ā'qa	sk'lak·s	skEmqi's	ma'lEmstlia	ts'ē	tQats	sk·Elā'ō
kEkū'ap	ckimrē's	gy'ēlā'una	nts'ē'tsim	stlātsī'nEm	cnē'ktltsā	stōnQ
ıqku'tlak	ni'pk·ō	tlā'utla	ka'qgen	tsu'pk·a	g·'atlg·'ā'tlē	sinā

[1] Borrowed from Kwakiutl. [2] Borrowed from Kwakiutl. [3] Borrowed from Bilqula. [4] = people of woods. [5] See flesh. [6] Borrowed from Tlingit. [7] Borrowed from Kwakiutl. [8] Borrowed from Bilqula.

Stock	Dialect	Fly	Mosquitoe	Snake
Tlingit	1 Stikeen	—	—	tl'ut tlā'k
Haida	2 Skidegate	dē'idEn	ts'Era'ltEguan	cik
Tsimshian	3 Tsimshian	—	gyī'ek	matqalā'ltq
Kwakiutl-Nootka	4 Hēiltsuk·	—	k·'a'ēqa	sī'tlEm
	5 Kwakiutl	—	—	sī'tlEm
	6 Nootka. Ts'ēciath	ma'tskwinE	tE'nakmis	hai'yē
Salish	7 Bilqula	mā'mic	—	papē'nkH
	8 Çatlōltq	—	ts'ā'djus	ōtlk·ā'i
	9 PEntlatc	—	tstcī'ōs	cī'ēsim
	10 Siciatl	—	stsetdjō'us	ōtlk·ā'i
	11 Snanaimuq	—	k·oaE'n	ātlk·ē'i
	12 Sk·qōmic	—	k·on'ē'matc	ātlk·ā'i
	13 LkuñgEn	k·Ek·ayē'qEna	pqoā'ēk·sEn	s'ō'tlk·ē
	14 Ntlakyapamuq	—	k·ō'k·oaskē	cmē'iq
	15 StlatlumH	Qmāts	k·oal'ē'mak	naqoī't
	16 SEQuapmuQ	Qma'yē	k·onē'mik·tl	tstlwa'woltsk
	17 Okana'k·ēn	qamā'tl	sElā'k·s	ckūkawi'lQaq
Kutonaqa	18 Columbia Lakes	yānuqk·tluk·'u'tlōp	k·atsetsa'tla	t'ā'u

Stock	Dialect	Salmon	Name	White	Black
Tlingit	1 Stikeen	g·āt	sāri'	tlēdi'qatē[1]	d'ō'utc
Haida	2 Skidegate	tcīn	—	g·ā'ta	tlk·'ātl
Tsimshian	3 Tsimshian	hân	wā	mâks	t'ō'otsk
Kwakiutl-Nootka	4 Hēiltsuk·	mēa'	—	mō'k·oa	ts'ō'tla
	5 Kwakiutl	mā	tlē'k·am	mE'la	ts'ō'tla
	6 Nootka. Ts'ēciath	me'āt	ai'miti	tli'suk	tu'pkuk
Salish	7 Bilqula	sEmlkH	tōm	tsq	skHst
	8 Çatlōltq	tlaqoā'ē	kū'ic	pE'k·pEk·	qus
	9 PEntlatc	k·ō'loq	kū'ic	çasqōs	çasqus
	10 Siciatl	skuō'lō	kū'ic	pEk·	—
	11 Snanaimuq	ts'ā'k·oē	kū'ic	pEk·	tsk·'ēq
	12 Sk·qōmic	—	kūi'ns	pEk·	k·Eqk·'ēq
	13 LkuñgEn	ctcai'nuq	kū'ic	pEk·	nEk·'ēq
	14 Ntlakyapamuq	sk·ēē'itEn	—	stpēk'	sti'ptipt
	15 StlatlumH	stsō'k·oats	skwa'tcitc	pEk·	k·'uq'ā'q
	16 SEQuapmuQ	skEla'ltEn	—	pEk·	k·uyuk·'ē't
	17 Okana'k·ēn	ndīdī'Q	skui'st	pEk·	k·'oā'i
Kutonaqa	18 Columbia Lakes	suwā'kemō	gā'ktlē	kamnu'qtlō	kāmk·'ōk·'ō'kutl

[1] =snowlike colour.

Bird	Feathers	Wing	Goose	Duck	Fish
ō'tli	k·'oā'tl	kitc	tā'wok	g'uts	hin tak'a'tē
ēt'ē't	g·ā'u	ɴēi	tlgyitgu'n	tha	tcitl
s'ō'wots	lī	k·'āk·'ā'i	hā'aq	mē'ᴇk	luwᴇ'lᴇm tsᴇm aks
s'ē'kō s'ēk	pā'tl'a ts'i'lkyᴇm	mā'tlmatᴇm p'ᴇ'tlᴇm	— nᴇ'qāk·	tlaā'tla tlā'tlkyō	mā'gyilis —
a'matlē	a'iātl	tla'phspātō	ho'k·sᴇm	nā'qtatc	ta'tluk
sitsīpē'	spōq	k·pō'otl	qā'qatl	—	—
·oak·ō'aq oē'lek· ō'ok· k·ulä'c oē'leq —	— stsō'ts'ok· — — stlpā'lqēn ts'ē'ek·t	— tlatlqals — — — ts'ēk·t	pā'k·'ēnatc qō'senatc pā'k·'ēnatc tlä'k·oaqan qō'ok·en tlä'k·oaqan	k·ēnk·ē'n tᴇ'nᴇk·sᴇn tᴇ'nᴇk·s tᴇ'nᴇk·sᴇn tᴇ'nᴇk·sᴇn tᴇ'nᴇk·sᴇn	djānq spē'p'açut ciā'nq slōk· ōtsts'ō'k·oi —
pᴇzu'zō pᴇō'ō	— ō'k'oal	— stlak·ā'al	k'oacī'q k'cē'uq	sqäk· sqäk·	— —
pīyū'	sqā'qpᴇls	skūkoa'qan	k'siq	s·āstlqō	cwā'utl
qᴇkā'ka	spūtlt	skᴇwā'qᴇns	k'siq	qoa'tqut	k·āk.qu'lq
ōk·utskā'mena	aqg·'uk·tlu'pk·a	aqkingō'ua	g·aqutlō'ok	gang·usk·ō'ēk·a	gia'kqō

Red	Light blue	Yellow	Light green	Great, Large: Independent	Great, Large: In compounds
k·'ani'qatē [1]	ts'ōyi'qatē	kyētlhatlē yi'qatē [2]	ts'ōyi'qatē	tlēn	—
sqē'it	g·ōtlratl	g'antlratl	g'antlratl	yū'ᴇn	—
mᴇsk	kuskua'sk	mᴇtlē'itk	mᴇtlē'itk	wī	—
tlā'k·oa tlā'k·oa	koā'yelaks tsā'ca	tē'qa —	tē'qa tlᴇ'nqa	k·'aiē'kyas wa'las [3]	—tsē —tsē
tlēhā'uk	kistā'k·ak·	tsitsitē'k·tl	āiyō'k·oak·	īh	—
mōk·	k·oī't	k·li		tlk·	—
tā'atsēm, ku'qoēm } kumē'p t'ētcē'm tskui'm kumkuī'm suk·	p'ā'tstᴇm p'ᴇtcē'm p'ᴇtcē'm tsä'tsᴇqum — ntl'ᴇtl	tl'ᴇsē'm tl'ᴇsē'm tl'ᴇsē'm tsk·oā'i tlstlēs ts'â'citl		tī tī tē'iē sī hē'iē tcᴇk·	— — — — — —
stcī'uk· tcuk·tcē'k·	stku'ltsk·ultst k·uzk·oā'z	stukulē't kākulä'a		qᴇzo'm qᴇo'm	— —
tsēk·[4]	k·uyuk·oē'it	koa'lt	k·uyuk·oē'it	q'iō'm	—
kui'l	k·oā'i	k·uri'	k·uri'	cī'luqoa, pl. pᴇᴇ'stlaat	—
kanō'hus	yami'nk·an	gak·tloi'tga	gē'ekōp	wi'tlk·a	—

[1] =firelike colour. [2] =dog-dung colour. [3] Tlatlasikoala : ōmas.

Stock	Dialect	Small, Little		Strong
		Independent	In Compounds	
Tlingit	1 Stikeen	ga'tskō	—	tliwu's
Haida	2 Skidegate	gE'dsō	—	diākuya'
Tsimshian	3 Tsimshian	tlgua	—	—
Kwakiutl-Nootka	4 Hēiltsuk·	hāula'tl	—	tlō'kuim
	5 Kwakiutl	āma'	—bēdō plural, mEnē'q	tlō'kuim
	6 Nootka. Ts'ēciath	anā'h'is	—is	na'cuk
Salish	7 Bilqula	k·ē'k·tē	—	ttl
	8 Çatlōltq	tc'ī'tcia	—	tlā'tlsam
	9 PEntlatc	çē'içōi	—	tlā't'am
	10 Siciatl	k·'ēquā'lō	—	skoā'mkum
	11 Snanaimuq	tlē'tsemats	—	kuā'mkum
	12 Sk·qōmic	atsī'm	—	ēiē'm
	13 LkuñgEn	tcitcē'itl	—	k'oā'mkum
	14 Ntlakyapamuq	k'umē'mat	—	—
	15 StlatlumH	k·wēk·s	—	rulral
	16 SEQuapmuQ	k'uiē'Esa; plural, tsitsi'tsEmaEt	—	yâyâ't, rilra'lt
	17 Okana'k·ēn	k'uiō'ma; plural, tcitcā'mat	—	g'utcgoa'tst
Kutonaqa	18 Columbia Lakes	tsek·u'na	—	tsemā'k·ek·a

Stock	Dialect	Warm	I	Thou	He
Tlingit	1 Stikeen	rE t'a	qat, qatc	woe', woe'tc	hu, hōtc
Haida	2 Skidegate	ky'ē'ina	dēa, tlā'a	dā'a, da'ñga	lāa
Tsimshian	3 Tsimshian	gyā'muk	nE'riō	nE'rEn	nē'EdEt
Kwakiutl-Nootka	4 Hēiltsuk·	kō'qoa	nō'gua	k·qsō	—
	5 Kwakiutl	ts'ī'lk·oa	nō'gua, yin	yūtl, sū'um	hē, yūt
	6 Nootka. Ts'ēciath	tl'u'pa	sē'ia	sō'ua	—
Salish	7 Bilqula	k·ul	ens	inō	(t'aiH)
	8 Çatlōltq	k'ō'as	djini'tl	nE'gī	—
	9 PEntlatc	k'ō'as	tcinē'itl	nuē'	—
	10 Siciatl	—	djini'tl	nū'ēla	—
	11 Snanaimuq	k·'oā'koas	te äns	te nō'ua	—
	12 Sk·qōmic	kuā's	te ens	nō'u	—
	13 LkuñgEn	k·'oā'les	a'sē	nō'kua	tsä'e
	14 Ntlakyapamuq	—	—	—	—
	15 StlatlumH	k·Emp	cEi'ntca	snō'a	cnē'itl
	16 SEQuapmuQ	sk·oā'ts	ntsā'wa	anū'ē	nuwē's
	17 Okana'k·ēn	kua'lt	Entā'kEn	hānuē'	tcinī'tl
Kutonaqa	18 Columbia Lakes	ū'temē	kamin	ninkō	ninkō'is

Old	Young	Good	Bad	Dead	Sick	Cold
:ān	ga'tskō	rE k'ē	tlētl uc k'ē [3]	na	nēk'	siā't
c'āi	g·i'tgE	lā	dā(rañga)	k·'ō't'utl	st'ē	quī'
wud'ā'gyat [1]	copac	ām	hada'q	ts'ak	sī'epk	qkua'tkō
c'u'liak' [2] c'ē'iōtl	— —	aikH aikH	iakH [3] iakH [3]	tlEl tlEl	tl'ō'qoala ts'ē'Hk·a	t'Enē'k' wu'tal
tc'i'mE	ta'nēis	tlōtl	p'i'cak·	k·a'hak	tē'itl	matlu'k
Hk·'ulkH		ia	sq	atE'ma	kH'imalai'kH	skH'ilkHts
qō'qook, tl'a'qai totlmā'i, stl'aq mā'yil, stlaq s'ä'laq sīō'yō s'ā'loq	=small	ai ai'ētō ai äi hā'atl aie	tlEq mā'i mā'i k·al k·ē'i sqā'a, k·al	k·ai'i tE'mEn k·'ō'i k·'ä'i k·'ō'i k·'ä'i	i gā'tak k·ā'k·alçut — k·ā'k·'ēi sk·'ō'i qā'itl'et	dj'im dj'im ctcimō'tl qä'itl t'ēk· q'ā'itl
k·atlnūn k·EtlmE'mEn	towē'wut,ckukumē't	ia' ā'ma	tl'ist k·El	zuk· ō'uk·	k·unu'q —	— qEtl
tsk'ā'wulH	tuwē'wut	la	ky'ēst	{ k·tsāk· pl. qoā'et	ky'ea'p	ts'ātlt
dlEqtlEqā'm	—	qāst	ky'āst	—	sk·'ē'lElt	ts'ātlt
kutla'ktlē	nā'na	sōk	sān	ōp	sē'ntlqō	sk·ā't'ēi

[1] =great man. [2] =old man. [3] =not good

We	Ye	They	This	That	All
ōhā'n, ōhā'ntc	rīwā'n, rīwā'ntc	has, hastc	rE tat	ru tat	—
ētl, d'alE'ñgua	dālE'ñ	laa (?)	—	—	tlō'qan
nE'rEm	nE'rEcEm	nē'EdEt	—	—	tqani
{ inclu. nōgoa'nts exclu. nōgoa'ntk }	k·aeksoā'ea	—	—	—	ā'gyem
{ inclu. nōgoame'nts yints exclu. yinuq }	sōqdâ'qEm	hē'qdâq, yū'qdâq	gya	yūt	k·'ā'laue
nē'wa	sī'wa	—	hi'tl'iē	a'qha	tc'ōtck
Hmītl	tlōp	ats	t'aiH	—	stai
nē'mōtl nē'mōtl nē'mōtl te tlnē'mētl te nē'matl tlnē'ñeitl	nō'uap nō'lap nō'lap te tlwē'lap te nuyā'p nEkuē'lēya	— — — — — tsā'ēyatltEn	— — — — nītl tlä'a	hē'itl — — — { tō'nītl, masc. çō'nītl, fem. } —	āuk ētē't — muk· ē'eq mEk·
— wucnē'mutl	— snōla'p	— wucnē'itl	— —	— —	tE'k·Em tā'k·Em
{ inclu. utlnuē'kt exclu. utlnuē'εskuQ }	utlmē'emp	utlnuē'es	—	—	tl'a'k·qEn
mnē'mltit	mnē'mtlEm	mnē'mtciliq	aQa'	iā'qis	yāyā'at
kawinā'tla	minkō'nisgītl	ninkō'isis	na	—	k·'ā'pē

Stock	Dialect	Many, Much	Who	Far	Near
Tlingit	1 Stikeen	k·tōq	adu′tsē	tlē	tlētl wu tlē[1]
Haida	2 Skidegate	skō′ul, k·oa′n, yū′ᴇn	gyīstō	dzi′ñga	ā′qan
Tsimshian	3 Tsimshian	hä′ldᴇ	gō	d′ā	—
Kwakiutl-Nootka	4 Hēiltsuk·	k·′ai′nᴇm	akoiqk·an	quē′sala	nᴇqoa′la
	5 Kwakiutl	k·′ai′nᴇm	ungwē	k·uēsa	nᴇqoa′la
	6 Nootka.Ts′ēciath	ai′a	atci′k·	saia′	anē′is
Salish	7 Bilqula	slaq	—	iq	ēkʜli
	8 Çatlōltq	k·eq	ñgā′tigat	nī′edji	ēiē′imik·
	9 Pᴇntlatc	k·eq	—	koā′ya	dje′ē′dji mit
	10 Siciatl	k·eq	—	tcuō′k	ēe′lwet
	11 Snanaimuq	k·eq	—	sāk·	tlētlk·ē′i
	12 Sk·qōmic	k·eq	—	qa′ta	ē′tc′ēt
	13 Lkuñgᴇn	ñgᴇn	—	lä′el	tlētlē′tlk·i
	14 Ntlakyapamuq	Quē′t	—	—	—
	15 Stlatlumʜ	Quē′t	cuwa′t	kakā′ō	k′ī′ktā
	16 SᴇQuapmuQ	Quē′t	—	kᴇkā′s	nᴇā′lie
	17 Okana′k·ēn	Quē′t	cuē′t	lkūt	gīk′ā′at
Kutonaqa	18 Columbia Lakes	ni′ntik	g·a′tlakī	wutlē′et	—

[1] Not far

Stock	Dialect	No	One	Two
Tlingit	1 Stikeen	tlēk‘	tlēq	dēq
Haida	2 Skidegate	gau′anō	{ squn, sqa′sgō, sqoā′nsᴇñ	stiñ
Tsimshian	3 Tsimshian	atlgᴇ	gyāk′, gāk′, g′ᴇ′rᴇl,k′āl	tᴇpqā′t, gō′upᴇl
Kwakiutl-Nootka	4 Hēiltsuk·	ky′ē ; ī, hī, wī	mᴇn	mātl
	5 Kwakiutl	ky′ē ; ī, hī, wī	num	mātl
	6 Nootka.Ts′ēciath	wēk, ī, hī	ts′ō′wak, nup	a′tlā
Salish	7 Bilqula	ā′qkō	(s)mā′otl	tlnōs
	8 Çatlōltq	Quō′k·	pā′a ; pēpā′a	sāa, sēsā′a
	9 Pᴇntlatc	—	tlt′âls, tlt′ā′lē	yisa′lâls, yāisā′lē
	10 Siciatl	—	pā′luls, nᴇtciā′lē	tᴇmci′nuls, tᴇmeinā′lē
	11 Snanaimuq	—	nᴇ′ts′a, nā′nᴇts′a	yisâ′oles, yā′isᴇla
	12 Sk·qōmic	—	ntc′ō′i, nᴇtcintcâ′s	ā′nos′ō′i, anā′nos
	13 Lkuñgᴇn	au′a	nᴇ′tsa, nâ′tse	tcᴇ′sa, tcā′asis
	14 Ntlakyapamuq	—	pē′ᴇ, papē′a	cē′ia, cicē′ia
	15 Stlatlumʜ	Qua′s	pᴇ′la	ā′nuᴇc
	16 SᴇQuapmuQ	ta′a	nᴇk‘ō	sᴇsā′la
	17 Okana′k·ēn	lōt	nak·s	acī′l
Kutonaqa	18 Columbia Lakes	māts	ō′kwē	ās

Here	There	To-day	Yesterday	To-morrow	Yes
—	—	iā'yigEri	tE'tgE	sērE'nk'	a
—	ēs	—	dā'rgatl tlga'ē	dā'rgatl	â, ō, ā'n̄ga
yā'gua	—	sēigya'wun	gyets'ē'ip	tsēgyets'ē'ip	ō
— —	— —	goa'k'Elai'oq qoanā'laq	tla'ntsē tlānsutla'	tla'nstlats tlE'nstla	lā'a lā'a
a'hkō	yītl	tla'h ūyē nāsiā'	amē'ūyē	a'mītlik	hāā
—	—	atisō'nHt	atlō'niHi	ikai'nuqs	ō'ua ; wisq
— — — — — tiā'kō	hē'itl'ōt — — — — tlā'akō	sts'ōk' koā'yil tEstsōk' tE nakuā'yil ti stsē'is tiā'anuk	cisniā'sōtl djilā'k·atlēt cisiā'sōtl tselā'k·atl kuitcil'ā'k·tl tcela'qatl	kū'isEm kū'içe kuī'skoa wukoā'yiles k·k·oā'ilas kukuā'tcilas	gyinaq — — — — —
— iltc'a'	— lā'ta ; iltEu', ElkEō'	cītlk'·at tc'a'kōsk'·ē'it	spēeqā'ut ina'tQuas	pēaqā'ut pcī'las	— ē
—	nō'nE	pīē'n	pEsts'a'tl	pEqiā'ut	mā
halā'	ky'Elā'	hā'pEna	p'ēstcitl	qEla'p	—
na	nē'e	nagyū'kēyit	wa'tlgoa	gaumī'yit	hē

Three	Four	Five	Six	Seven
natsk'	dak·'ō'n	kēdji'n	tlēdurcu'	daqadurcu'
dlk·u'nutl	sta'nsEn̄	tlētl	dlk·unō'utl	dzi'gura
gua'nt, gutlē'	tqālpq	kctōnc	k·âlt	t'Epqâ'lt
yūtq yūtq	mō mū	siky'a' siky'a'	k·atla' k·atla'	mātlaau'sis [1] a'gdlibū
k·a'tstsa	mō	sū'tca	nō'pō	a'tlpō
asmōs't	mōs	tsēH	tqōtl	nūstlnōs
tsiā'tlas, siā'tla tlēqâ'ls, tlēqoā'lē tcāatlā'suls, tciatlā'lē tlē'Quis, tlQuā'la tcā'nat'ōi, tcintcā'nat tlēQ, tlQuā'l	mō'sa q'ō'sēna q'ōsenā'lē qā'çinis, qaç'ē'le { qaō'tsen'ōi, { qaq'ō'ētsen n̄âs, n̄esa'la	tsēatsā'ē nukuā'tcisa silatcsā'lē tlqā'tses { tsēyatcis'ōi { tsītcē'atcis tlk·'ā'tcis	t'aqaniā'ē p'ultsō'ēa tEqEmā'lē tqam { t'ā'qatc'oi { tqtā'qats tqan̄	ts'utcisā'ē ts'ō'ētcis ts'ōtcisā'lē ts'ā'uks { t'ākōsaik'ō'i { tktā'kōsats ts'â'kus
kēEtlE'c, kēkaEta'c kāEtlā'c	mūs, mū'smEs qoō'tcin	tcīkst, tcī'tcīkst tcī'likst	{ tl'a'k·amakst { tl'ak·tlak·amakst tl'ā'k·Emkist	{ tcutlka { tcutltcutlka tcū'tlaka
kEtlā's	mōs	tsī'likst	tkmākst	tsōtslka
kā'tlēc	mōs	tcīlkHst	t'ā'k·EmkHst	aī'spilk'
g·a'tlEa	qā'tsa	iē'hkō	nmi'sa	nsta'tlā

[1] Seven men.

Stock	Dialect	Eight	Nine	Ten
Tlingit	1 Stikeen	naskadurcu′	gō′cuk·	djī′nkat
Haida	2 Skidegate	stu′nsEñra	tlālEñ sqoa′ñsEñ	tlā′atl
Tsimshian	3 Tsimshian	guandā′lt, yuktâ′lt	kctEmâ′c	gy′ap, k′pē′el
Kwakiutl-Nootka	4 Hēiltsuk·	yūtqō′tis	māmanē′is	a′kyas′is
	5 Kwakiutl	mā′tlguanatl	nā′namā	lastū′
	6 Nootka. Ts′ēciath	ā′tlakuatl	ts′ō′wakutl	hai′ū
Salish	7 Bilqula	k′ētlnō′s	k′esmā′n	tskHlākHt
	8 Çatlōltq	taatcisā′ē	tigeqoā′ē	ōpanā′ē
	9 PEntlatc	tā′atcis	tā′wiq	tlk·ō′ya
	10 Siciatl	tāatcisālē	tūwēquā′lē	ōpanā′lē
	11 Snanaimuq	tqä′tse	tūō′q	â′pEn
	12 Sk·qōmic	tqā′tc′ōi, tqtqātc	tssō′i, ts′E′sts′Es	ō′pan, opō′pEn
	13 LkuñgEn	tä′asEs	to′kuq	â′pEn
	14 Ntlakyapamuq	piō′pst	tEmtlpä′a	ō′pEnakst, ō′papEnakst
	15 StlatlumH	p′El′ō′opct	k·′ampā′lEmEn	k·′amp
	16 SEQuapmuQ	nEk′ōps	tEmtlEnkō′k′a	ō′pukst
	17 Okana′k·ēn	tī′mitl	qEqEn′ō′t	ō′penkHst
Kutonaqa	18 Columbia Lakes	ōuqa′tsā	g·aik·′i′t′ōwō	ē′t′ōwō

Stock	Dialect	One thousand	To eat	To drink	To walk
Tlingit	1 Stikeen	—	qa	tana′	gōd, at
Haida	2 Skidegate	lā′gua tlā′lē tlā′atlē	ta	qōtEl	k·a
Tsimshian	3 Tsimshian	k‘pâl	yā′wig, pl. gap	aks	iā
Kwakiutl-Nootka	4 Hēiltsuk·	—	ha′msa	nā′k·a	tōua′
	5 Kwakiutl	lō′qsEmHit	ha′mH′it	nā′k·a	k·ā′sat
	6 Nootka. Ts′ēciath	sūtc′ēk·pEtūk·	hā′uk·	na′kcitl	iā′tscitl
Salish	7 Bilqula	—	atltp	k·ā′aqla	tl′ems
	8 Çatlōltq	tEsā′itc	ē′tltEn	k·ō′ok·ō	ē′emes, çō
	9 PEntlatc	tlqoā′witc	ē′tltEn	k·ō′ok·oa	ē′mai, çō
	10 Siciatl	ts′ā′witc	ē′tltEn	k·ō′k·oa	tçō
	11 Snanaimuq	â′pEn näts′ō′wuts	ā′tltEn	k·ā′k·a	ī′mic, näm
	12 Sk·qōmic	nā′tcauwitc	ē′tltEn	täk·t	ē′maç, näm
	13 LkuñgEn	ōpā′anitc	ē′tlEn	k·oā′k·oa	ctEñg
	14 Ntlakyapamuq	ōpena qatsqk·äk·ankst	tlaqa′nc	ō′k·oaa	QuEcī′t
	15 StlatlumH	—	ē′tlEn	ō′k·oaa	—
	16 SEQuapmuQ	ōpukstqatspk·ē′k·enkst	s′ē′tlEn	sta	skūuwā′tEm, pl. Qusā′t
	17 Okana′k·ēn	—	s′ē′tlEn	cī′uct	k·′ō′lEm
Kutonaqa	18 Columbia Lakes	gyit′uwō tlEtuwō′nōwō	ik	i′kwūtl	—

Twenty	Thirty	Forty	One hundred
tlē'k·a [1]	natsk'djinkā't	dak·'ō'n djinkā't	kē'djin k·a
lag·usqaa'nēgō	tlā'lē dlk·u'nutl	tlā'lē sta'nsEñ	lā'gua tlā'atl
kyēdē'el	gulē'wulgyap	tqālpwulgyap	kcEnEcâ'l
māsEmkuis tē'uais mātlsEmgyustau	yūtqsō'kē yūtqsum gyustāu	mō'qsokuē mōsk·Emgyaskaū	— lā'kyint
tsa'k·ēits	tsa'k·ēits ic hai'ū	atlē'k·	sūtc'ēk·
tlnōswos tskHlakHts	asmō'ses tskHlakHts	mōses tskHlakHts	ts'ē'Holaqs
sEmciā'a sEmciā'a sEmciā'lē tskuc wūtltc'ōi, wutlwutltc ts'uqk·'u's	djenoqsiā'a tlēqoatciā'a tciqoatlciā'a tlEqutlciā' tluqttlcō'i tlkEtctlcā'e	mōsatsiā'a q'ōsenatciā'a qōsEnatlciā'a qāsEntlciā' qaōtsnEtlcā'a ñgstlcā'e	tEsā'itc tlqoā'witc ts'ā'witc nāts'ō'wuts nā'atcauwitc nā'ts'ōtc
citlō'penakst ā'nuEc k·'amps	katlō'penakst kāEtlā'c k·'amps	mōtl ō'penakst qoō'tcin k·'amps	qatsqk·ā'k·ankst qtcEpk·ē'k·enkHst
sitl ō'pukst	kitl ō'pukst	mEtl ō'pukst	qatspk·ē'k·enkst
asilE ō'penkHst	k·ā'tElE ō'pEnkHst	mistlE ō'penkHst	qatcitci'kst
ai'wō	g·atlsā'nōwō	qātsa'nōwō	gyit'uwō'nōwō

[1] =one man.

To dance	To sing	To sleep	To speak	To see	To love
a—tl'ēq	ci	ta	yu'q'a—tEñ	tēn	sg·an
Hiā'tl	sqāla'ñ	k·'a	—	k·iñ	stat'E'l
halā'it	lī'ēmi	qstoq	a'lgiaq	nē	hasā'oknEnan
yi'qoa yi'qoa	nē'nōya sā'lala	gy'ā'tla mē'q'ēt	bgoa'la [1] bagua'la [1]	dō'k·oa dō'k·oala	— —
?	nūnū'k	wā'itc	wāwa	na'tsa	—
nā'aqum	nūya'm	tsītō'ma	—	kH'H	anoai'kH
tsī'tlEm ē'ius k·uiyē'les k·oiē'les wumē'tla k·'oē'les	wōwō'm lō'lom st'ē'lēm t'ē'talEm wunumapaā'yicis tEtlē'elEm	tlā'tsit ē'tut ē'etut ē'tut ē'tut ē'tut	k·oā'i, ōtlōtas — — — — —	k·u'nēim lā'mat k·'u'nēm lā'mat kuā'kt k·'u'nēt	— — — — — —
k·o'ētcūt mō'ts'um	ī'tl'Em ē'tl'Em	ōk·ō'it roi'it	— k·oalō't	wī'k'Em ā'tsqan	— qā'tlmēn
stl'ā'ē	sī'EmtEna'm	pElē't, pl. qEmkā'ut	k·Elū't, pl. k·oā'les	wē'kEm	—
sk·'oiē'liq	sEnkunē'Q	ītQ, pl. ts'ātQē'liQiQ	k·ulk·Qē'lElt, pl. sk·oāk·oa'l	wē'kEn	iqamē'n
k·ā'k·auwītl	gawasqōnī'am	g·'ōm	k·a'kyē	u'pqa	—

[1] = man speaks; k·kya'la, woman speaks.

Stock	Dialect	To kill	To sit	To stand	To leave
Tlingit	1 Stikeen	—	—	gya	gōd
Haida	2 Skidegate	tē'aqan	k·'au'ō	giā'rañ	k·a
Tsimshian	3 Tsimshian	ds'ak	d'a	hā'yitk	dā'wult
Kwakiutl-Nootka	4 Hēiltsuk·	ha'ıqa	gua—	tlā—	—
	5 Kwakiutl	tlatlala'	gua—	tla—	pâ'o
	6 Nootka.Ts'ēciath	k·a'hsop	—	—	—
Salish	7 Bilqula	—	āmt	anoētlmē'iq	taiā'mkits
	8 Çatlōltq	cEqoā'itEm	āmō't	çEk·ā't	ē'mac
	9 PEntlatc	kutE'mEn	ā'mōt	—	ē'mai
	10 Siciatl	—	amō't	skoē'cit	ē'mec
	11 Snanaimuq	—	â'omat	ck·ät	hā'ya
	12 Sk·qōmic	—	ā'mōt	stsEtsk·	ē'mac
	13 LkuñgEn	k·'oā'tcit	ā'mat	—	i·ā'a
	14 Ntlakyapamuq	—	mi'tcaak·	tē'tliQa	—
	15 StlatlumH	ōk·s	mī'tcak·	tā'tEIQ	k·oatcā'tc
	16 SEQuapmuQ	pōl'stEm, plural tl'ē'k·un	mō't, plural tsiā'm	stslā'ut	k·utsā'ts
	17 Okana'k·ēn	kspō'lstEm, pl. stlEquntē'm	mōt, plural kōkulē'ut	aksuwē'Q, plural t'ōwē's	—
Kutonaqa	18 Columbia Lakes	—	sānk·'ā'mit	gāwi'sk·a	—

Errata in the Fifth Report of the Committee.

[The occurrence of these errors may be ascribed mainly to the distance between printer and author, preventing a proper revision of the proofs.]

Page 806, line 8, *instead of* P·E'ntlatc *read* PEntlatc.
„ 808, „ 36, „ jaw *read* chin.
„ 821, „ 15, „ g'anō'k *read* g·anō'k.
„ „ last line, „ snow *read* town.
„ 822, line 18, „ waski *read* wask·.
„ 823, „ 8, „ k'ōk' *read* k'ōk'.
„ 824, „ 21, „ (raven)= *read* =(raven).
„ 825, „ 10, „ K·omō'k·oa *read* Komō'k·oa.
„ 827, „ 22, „ Lâgsē *read* Lâqsē.
„ „ „ 30, „ Tsētsētloa'lak'amaē *read* Tsētsētloa'lakiamaē.
„ „ „ 30, „ Gyī'gyitk·am *read* Gyī'gyilk·am.
„ 828, „ 2, „ Ts'E'nHk·'aiō *read* TsE'nHk·aiō.
„ 829, „ 42, „ K'ōmena'kula *read* K·ōmena'kula.
„ 830, last line, „ 1888 *read* 1890.
„ 831, line 13, „ any other *read* any.
„ 836, „ 23, „ Kemiaminow *read* Vemiaminov.
„ 841, „ 52, „ place, or *read* place in.
„ 846, „ 22, „ good *read* food.
„ 847, „ 32, *omit* (with outspread wings).
„ „ „ 43, *instead of* k·'oā'qaten *read* k·oā'qaten.
„ 849, „ 13, „ maple *read* alder.
„ 852, „ 45, „ Ts'ilky- *read* Ts'ilky-.
„ 860, „ 24, „ ttētl *read* tlētl.
„ „ „ 32, insert *ti* in beginning of line.
„ 861, „ 8, *instead of* tlīqa *read* tlī qa.
„ 863, „ 37–42, „ k·' *read always* k·'.
„ 864, „ 37, „ gadE *read* qadE.
„ „ „ „ „ k·a t gadE' *read* k·a tō qadE
„ 865, „ 9, „ nēk' *read* nēk'.
„ 867, „ 13, „ su q· *read* su q.

To come	To run	To steal	To lie down	To give	To laugh	To cry
hatkō'atin	—	tāō	—	djēt—tē	at–cō'uk·	g·āq
—	k·ā'Hit	k·'ō'tlta	—	ē'ista	k·ā	sk·ā'itEl
kâ'edEks	ba	—	nâg	gyEnā'm	sis'a'qs	wīhā'ut [1]
gyā'qa gyā'qa	— —	— gyilū'tla	— kulē'tl	— —	— —	k·'oā'sa k·'oā'sa
i'natscitl	—	kō'witl	—	hinnē'	—	äihak
pōtl	ia'tlimoq	ō'laqits	āqts	nap	itlk·'ō'nH	koana'ts
k·ul mē'la qutl — mē'ka —	çōdjitl lā'tcinam tlē'etcin — tsk'oā'tsut iā'la	tciō'oten k·ān tci'Tōtl sk·ēn k·ān k·ān	ā'qis ā'qis ā'qis sEnī's — —	k·ola's eā'sē — â'qus sā'tcit sā'ñgats	— nī'em qā'aqiam yE'nEm qā'yentcin —	tlō'quit qā'wan qā'qawun qäm qām qoā'am
— nāc	— k·'ē'tlēl	— nāk·'	— kā'kEzāa	— ō'mEn, Quī'tsHit	— k·'ak·'acā'nik	wowī'iq ē'lal
tsnas	nā'wulq	—	—	—	{ wulē'lem qoi qoa'yōs }	{ tsEō'm, pl. k·oa'k·t
—	k·ē'tciliq, pl. Qē'tEmēst	snāk·	—	Quē'tsiQt	sā'intcūt	tskoāk·
a'qē	hāutlu'pk·an	—	·a· k·qka	—	ōma'ts	tlān

[1] =great say.

Page 867, line 19, *instead of* to *read* tō.
„ „ „ 22, „ te *read* tē.
„ 869, „ 17, „ *stiñ read stīñ.*
„ 870, „ 25, „ then *read* there.
„ 871, „ 7, „ k·uñ—ra *read* k·uñra.
„ „ „ 32, „ gya'gen *read* gya'gEn.
„ „ „ 45, „ tlgogai *read* tlgagai.
„ 875, „ 8, „ lu'nsēda *read* l u'nsēda.
„ „ „ 19, „ k·ā'itlñā'ga *read* k·āitlñā'ga.
„ 876, „ 30, „ yū'Eñga *read* yū'Enga.
„ „ „ 31, „ yū'EñgEn *read* yū'EngEn.
„ „ „ 43, „ hi *read* Hi.
„ 877, „ 34, „ a'ldēgi *read* ha'ldēgi.
„ „ „ 49, „ ts'ēn *read* ts'ēn.
„ 878, „ 14, „ stz *read* sts.
„ 879, „ 19, „ k āina *read* k·āina.
„ „ „ 22, „ ds'ak' *read* ds'ak'.
„ „ „ 24, „ wātk' *read* wātk'.
„ „ „ 26, „ ds'ak' *read* ds'ak'.
„ „ „ 48, „ Dords *read* Dzords.
„ 883, „ 2, „ sāwuus *read* sāwuns.
„ „ „ 29, „ sī'epgEt *read* sī'ēpgEt.
„ 884, last line, „ wa'usEm *read* wā'nsEm.
„ 886, line 31, „ sissisī'epkEnō *read* sissisī'ēpgEnō.
„ „ „ 35, „ sī'epkEnō *read* sī'ēpgEnō.
„ „ „ 50, „ t'ō'uskEnō *read* t'ō'usgEnō.
„ 887, „ 22, „ yā'niqk·En *read* yā'wiqk·En.
„ „ „ 30, „ hatlEbī'etsgEda *read* hatlEbī'etsgE da.
„ 888, „ 14, „ k·amē'eleq *read* k·amē'elEq.
„ „ „ 39, „ En'o'n *read* ano'n.
„ „ „ 43, „ se *read* sE.
„ 890, „ 21, „ gyit'uwō'nōwō *read* gyit'uwō'nōwō
„ 892, „ 37, „ giantlikqō *read* giantli'kqō.
„ 893, „ 32, „ vibrate *read* verbal.

TRANSACTIONS OF THE SECTIONS.

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Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section—J. W. L. Glaisher, Sc.D., F.R.S , V.P.R.A.S.

THURSDAY, SEPTEMBER 4.

The President delivered the following Address :—

No one who is called upon to preside over this section can fail to be struck by the range of subjects comprehended within its scope. The field assigned to us extends from the most exact of all knowledge, the sciences of number, quantity, and position, to branches of inquiry in which the progress has been so slight that they still consist of little more than collections of observed facts. This breadth of area has obvious disadvantages, but it is not without some compensating advantages. In these days when science is so much subdivided it is well that students of subjects even so diverse as those with which we have to deal should occasionally meet on common ground, and have the opportunity of learning from each other's lips the kind of work in which they are engaged. Wide as is our range, we should remember also how closely knit together in various ways are the more important of our subjects; and in the case of Mathematics, Astronomy, and Physics, besides their actual and historical alliance, a mathematician may be permitted to feel that a special bond of union is created by the mathematical processes and language which are essential for their investigation and expression.

It is, I am afraid, unfortunate for my audience, that my own subject should be at one extreme, not only of those dealt with by our section, but even of the still greater range covered by the Association. I will endeavour, however, in my remarks to confine myself to a few general considerations relating to pure mathematics which I hope will not be considered out of place on this occasion.

By pure mathematics I do not mean the ordinary processes of algebra, differential and integral calculus, &c., which every worker in the so-called mathematical sciences should have at his command. I refer to the abstract sciences which do not rest upon experiment in the ordinary sense of the term, their fundamental principles being derived from observations so simple as to be more or less axiomatic. To this class belong the theories of magnitude and position, the former including all that relates to quantity, whether discrete or continuous, and the latter including all branches of geometry. The science of continuous magnitude is alone a vast region, containing many beautiful and extensive mathematical theories. Among the more important of these may be mentioned the theories of double and of multiple periodicity, the treatment of functions of complex variables, the transformation of algebraical expressions (modern algebra), and the higher treatment of algebraical and differential equations as distinguished from their mere solution. It is this kind of scientific exploration which fascinates and rewards the pure mathematician, and upon which his best work is most profitably spent. I do not wish to under-estimate the importance of such a subject as Finite Differences, in which a number of distinct problems are treated with more or less success by interesting methods specially adapted to their solution. Nor would I willingly undervalue the interest of those branches of mathematics which we owe to the mathematical necessities of physical inquiry. But it always appears to me that there is a certain perfection, and also a certain luxuriance and exuberance, in the pure sciences which have resulted from the unaided, and I might almost say inspired, genius of the greatest mathematicians which is conspicuously absent from most of the investigations which have had their origin in the attempt to forge the weapons required for research in the less abstract sciences. To illustrate my meaning, I may take as an example of a subject of the latter class the theory of Bessel's functions. The object of mathematicians in this case has been to investigate the properties of functions which have already presented themselves in Astronomy and Physics. Formulæ for their calculation by means of series, continued fractions, definite integrals, &c., have been obtained in profusion, numerous theorems of various kinds and applicable to different purposes have been discovered, extensions and developments have been made in all directions, and finally the large body of interesting analysis thus accumulated has been classified and systematised. But, valuable and suggestive as are many of the results and processes, such a collection of facts and investigations is necessarily fragmentary. We do not find the easy flow or homogeneity of form which is characteristic of a mathematical theory properly so called. In such a theory, as for example the theory of double periodicity (elliptic functions), the subject develops itself naturally as it proceeds; one group of results leads spontaneously to another; new and unexpected prospects open of themselves; ideas the most novel and striking, which penetrate the mind with a charm of their own, spring directly out of the subject itself. We are surprised by the wonderful connections with other subjects which unexpectedly start into existence, and by the widely different methods of arriving at the same truths; in fact, as our knowledge progresses, we continually find that results which seemed to lie far away in the interior of the subject—so remote and concealed that, at first sight, we might think that no other path except the one actually pursued could have reached them—are actually close to its edge when approached from another side, or viewed from another standpoint. We notice, too, that any great theory gives rise to its own special analysis or algebra, frequently connecting together into one whole what were hitherto merely isolated and apparently independent analytical results, and affording a reason for their existence, and also—what is often even more interesting—a reason for the non-occurrence of others which analogy might have led us to expect. I do not pretend that there are not many branches of mathematics which partake of both these characters, nor do I suppose that the description I have given of a mathematical theory is at all peculiar to pure mathematics. Much of it is common to all scientific research in a fruitful field, though, possibly, we may not find elsewhere such profusion of ideas or perfection of form.

I have been tempted to speak at such length on the objects and aims of the mathematician by the feeling that they are not infrequently misunderstood by the workers in the less abstract sciences. I do not think that mathematical formulæ or processes, merely as such, are much more interesting to the pure than to the applied mathematician. The one studies number, quantity, and position, the other deals with matter and motion; and in both cases the investigations are carried on by means of the same symbolic language.

The order in which the subjects which form an ordinary mathematical course are presented to the student is regulated by the fact that portions of the elements of the pure sciences are required for the explanation and development of any exact science; for example, a knowledge of the elements of trigonometry, analytical geometry, and differential and integral calculus, must necessarily precede any adequate treatment of mechanics, light, or electricity. The majority of students, after mastering a sufficient amount of pure mathematics to enable them to pass on to the physical subjects, continue to devote their attention to the latter, and never know more of the nature of the pure sciences than they can derive from the processes and methods which they learned at the very outset of their mathematical studies. This is necessarily the case with many of the wranglers, as the first part of the mathematical tripos includes no true mathematical theory. Most of the mathematical text-books in use at Cambridge are so admirably adapted to the purposes for which they are intended that it seems ungracious to make an adverse criticism of a general kind. But I cannot help feeling regret that their writers have had so much in view the immediate application of the principles of the pure subjects to the treatment of physical problems. In the case of the differential and integral calculus, for example, there seems an increasing tendency to introduce into the bookwork and examples propositions which really belong to the physical subjects. This is an important tribute to the growth and influence of physical mathematics in this country, and a zealous physicist might even consider it satisfactory that the student should not be required to encumber himself with knowledge which was not directly applicable to the theory of matter. But from the mathematician's point of view it is unfortunate, for, while shortening by very little the path of the student, it cannot fail to give an incomplete, if not erroneous, idea of the relations of the pure to the applied sciences. How can he help feeling that the former are merely ancillary to the latter when he finds that the mathematical problems which arise naturally in physical investigations have been already dealt with out of their place in the treatises which should have been devoted solely to the sciences of quantity and position?

Perhaps few persons who have not had the matter forced upon their attention fully realise how fragmentary and unsatisfactory is the treatment of even those fundamental subjects in pure mathematics which form the groundwork of any course of mathematical study. Algebra is necessarily the first subject set before the student; it has therefore to be adapted to the beginner, who at that time is only learning the first elements of the language of analysis. It is customary to regard trigonometry as primarily concerned with the solution of triangles; the geometrical definitions of the sine and cosine are therefore adopted, and after the application of the formulæ to practical measurement and calculation a new departure is made with De Moivre's theorem. The elementary portions of the theory of equations and the differential and integral calculus and differential equations are valuable collections of miscellaneous principles, processes, and theorems, useful either as results or as instruments of research, but possessing no great interest of their own. Analytical geometry fares the best, for it includes one small subject—curves of the second order—which is treated scientifically and with thoroughness. It is true, however, that the course of reading just mentioned includes one theory which, though itself an imperfect one, receives a tolerably complete development—I mean the theory of single periodic functions: but it is dispersed in such small fragments among the various subjects that it does not naturally present itself to the mind as a whole. If we could commence this theory by considering analytically the forms and necessary properties of functions of one period (thus obtaining their definitions as series and products), and could then proceed to a detailed discussion of the functions so defined—including their derivatives, the integrals involving them, the representation of functions by their means in series (Fourier's theorem), &c.—we should obtain a connected system of results relating to a definite branch of knowledge which would give a good idea of the orderly development of a mathematical theory; but the fact that the student at the time of his introduction to sines and cosines is supposed to be ignorant of all but the most elementary algebra places great difficulties in the way of any such systematic treatment of the subject.

Passing now to the consideration of pure mathematics itself, that is to say, of the abstract sciences which can only be conquered and explored by mathematical methods, it is difficult not to feel somewhat appalled by the enormous development they have received in the last fifty years. The mass of investigation, as measured by the pages in Transactions and Journals, which are annually added to the literature of the subject, is so great that it is fast becoming bewildering from its mere magnitude, and the extraordinary extent to which many special lines of study have been carried. To those who believe, if any such there are, that mathematics exists for the sake of its applications to the concrete sciences, it must indeed seem that it has long since run wild, and expanded itself into a thousand useless extravagances. Even the mathematician must sometimes ask himself the questions—not unfrequently put to him by his friends—'To what is it all tending? What will be the result of it all? Will there be any end?' The last question is readily answered. There certainly can be no end; so wide and so various are the subjects of investigation, so interesting and fascinating the results, so wonderful the fields of research laid open at each succeeding advance—no matter in what direction—that we may be sure that, while the love of learning and knowledge continues to exist in the human mind, there can be no relaxation of our efforts to penetrate still further into the mysterious worlds of abstract truth which lie so temptingly spread before us. The more that is accomplished, the more we see remaining to be done. Every real advance, every great discovery, suggests new fields of inquiry, displays new paths and highways, gives us new glimpses of distant scenery. This wonderful suggestiveness is itself one of the marks of a true theory, one of the signs by which we know that we are investigating the actual, existing truths of nature, and that our symbols and formulæ are expressing facts quite independent of themselves, though decipherable only by their means. As for the other questions, it is very difficult to render intelligible even to a mathematician the kind of knowledge acquired by mathematical research in a new field until he has made himself acquainted with its processes and notation, and we cannot hope to find in the remote regions of an abstract science many results so simple and striking as to appeal forcibly to the imagination of those who are unfamiliar with its conceptions and ideas. It would seem therefore that the question, 'To what is it all tending?' could never be answered in general terms. I do not think any mathematician could see his way to a reply, or even give definite meaning to the question. He might feel daring enough to predict the probable drift of his own subject, but he could scarcely get a broad enough view to enable him to indulge his fancy with respect to more than a very minute portion of the field already open to mathematical investigation. To the outsider I am afraid that the subject will continue to present much the same appearance as it does now; it will always seem to be stretching out into limitless symbolic wastes, without producing any results at all commensurate with its expansion.

Instead of attempting to consider the general question of what may be expected to result from the progress of mathematical science, we may restrict ourselves to asking whether the great extension of the bounds of the subject which is taking place in our time, will materially add to its powers as a weapon of research in the concrete subjects. This is a question of the highest interest, and one that cannot fail to have occupied the thoughts of every mathematician at some time or another in the course of his work. For my own part, I do not think that the bearing of the modern developments of mathematics upon the physical sciences is likely to be very direct or immediate. It would indeed be rash to assert that there is any branch of mathematics so abstract or so recondite that it might not at any moment find an application in some concrete subject; still, it seems to me that, if the extension of the pure sciences could only be justified by the value of their applications, it is very doubtful whether a satisfactory plea for any further developments could be sustained. As a rule each subject involves its own ideas and its own special analysis, and it can only occasionally happen that analytical methods devised for the expression and development of one subject will be found to be appropriate for another. It is obvious also that the chance of such applications becomes less and less as we travel farther and farther from the elementary processes and methods which are common to all the exact sciences. There is a general resemblance of style running through much of the analysis required in the physical sciences, but there is no such resemblance in the case of the pure sciences, or between the pure and the physical sciences. It appears likely therefore that, in the future, the mathematical obstacles which present themselves in physical research will have to be overcome, as heretofore, by means of investigations undertaken for the purpose, and that analysis will continue to be enriched by conceptions and results, and even by whole subjects (such as spherical harmonics), which will be entirely due to the concrete sciences. Of course, it will sometimes happen that a differential equation or an integral has already been considered in connection with some other theory, or a whole body of analysis or geometry will suddenly be found to admit of a physical interpretation; but, after all, even the pure sciences themselves exert but an indirect effect upon the perfection of mathematical formulæ and processes, and we must be prepared to find that in general the requirements of physics have to be met by special analytical researches. Having now endeavoured to consider the proposed question impartially, and from a cold and rational standpoint, I cannot refrain from adding that, in spite of all I have said, I believe that every mathematician must cherish in his heart the conviction that at any moment some special analysis, devised in connection with a branch of pure mathematics, may bear wonderful fruit in one of the applied sciences, giving short and complete solutions of problems which could hitherto be treated only by prolix and cumbrous methods. For example, it is difficult to believe that the present unwieldy and imperfect treatment of the Lunar Theory is the most satisfactory that can be devised. We cannot but hope that some happy discovery in pure mathematics may replace the clumsy and tedious series of our day by simple and direct analytical methods exactly suited to the problem in question. In the different branches of pure mathematics, we find not infrequently that researches connected with one subject incidentally throw a flood of light upon another, and that we are thus led to solutions of problems and explanations of mysteries which would never have yielded to direct attack in the complete absence of any guide to the proper path to be pursued. So, too, in the Lunar Theory, if the direct attack should fail to supply any better treatment of the subject, we cannot but hope that some day the development of a new branch of mathematics, entirely unconnected with dynamics, may supply the key to the required method. It should be remembered also that dynamics, which differs from the pure sciences only by the inclusion of the laws of motion, is but little removed from them in the character of its more general problems.

It would seem at first sight as if the rapid expansion of the region of mathematics must be a source of danger to its future progress. Not only does the area widen, but the subjects of study increase rapidly in number, and the work of the mathematician tends to become more and more specialised. It is of course merely a brilliant exaggeration to say that no mathematician is able to understand the work of any other mathematician, but it is certainly true that it is daily becoming more and more difficult for a mathematician to keep himself acquainted, even in a general way, with the progress of any of the branches of mathematics except those which form the field of his own labours. I believe, however, that the increasing extent of the territory of mathematics will always be counteracted by increased facilities in the means of communication. Additional knowledge opens to us new principles and methods which may conduct us with the greatest ease to results which previously were most difficult of access; and improvements in notation may exercise the most powerful effects both in the simplification and accessibility of a subject. It rests with the worker in mathematics not only to explore new truths, but to devise the language by which they may be discovered and expressed; and the genius of a great mathematician displays itself no less in the notation he invents for deciphering his subject than in the results attained. There are some theories in which the notation seems to arise so simply and naturally out of the subject itself, that it is difficult to realise that it could have required any creative power to produce it; but it may well have happened that in these very cases it was the discovery of the appropriate notation which gave the subject its first real start, and rendered it amenable to effective treatment. When the principles that underlie a theory have been well grasped, the proper notation almost necessarily suggests itself, if it has not been already discovered; but some sort of provisional notation is required in the early stages of a theory in order to make any progress at all, and the mathematician who first gains a real insight into the nature of a subject is almost sure to be the first to seize upon the right notation. I have great faith in the power of well-chosen notation to simplify complicated theories and to bring remote ones near; and I think it is safe to predict that the increased knowledge of principles and the resulting improvements in the symbolic language of mathematics will always enable us to grapple satisfactorily with the difficulties arising from the mere extent of the subject.

Quite distinct from the theoretical question of the manner in which mathematics will rescue itself from the perils to which it is exposed by its own prolific nature is the practical problem of finding means of rendering available for the student the results which have been already accumulated, and making it possible for a learner to obtain some idea of the present state of the various departments of mathematics. This is a problem which is common to all rapidly moving branches of science, although the difficulties are increased in the case of mathematics by its wide extent and the comparative smallness of the audience addressed. The great mass of mathematical literature will be always contained in journals and transactions, but there is no reason why it should not be rendered far more useful and accessible than at present by means of treatises or higher text-books. The whole science suffers from want of avenues of approach, and many beautiful branches of mathematics are regarded as difficult and technical merely because they are not easily accessible. Ten years ago I should have said that even a bad treatise was better than none at all. I do not say that now, but I feel very strongly that any introduction to a new subject written by a competent person confers a real benefit on the whole science. The number of excellent text-books of an elementary kind that are published in this country makes it all the more to be regretted that we have so few that are intended for the more advanced student. As an example of the higher kind of text-book, the want of which is so badly felt in many subjects, I may mention the second part of Professor Chrystal's Algebra, published last year, which in a small compass gives a great mass of valuable and fundamental knowledge that has hitherto been beyond the reach of an ordinary student, though in reality lying so close at hand. I may add that in any treatise or higher text-book it is always desirable that references to the original memoirs should be given, and, if possible, short historical notices also. I am sure that no subject loses more than mathematics by any attempt to dissociate it from its history.

There is no more striking feature in the mathematical literature of our day than the numerous republications in a collected form of the writings of the greatest mathematicians. These collected editions not only set before us as a whole the complete works of the masters of our science, but they make it possible for others besides those who reside in the vicinity of large libraries to become acquainted with the principal contributions with which it has been enriched in our century; and, besides being of immense advantage to the science at large, they even go some way towards supplying the want of systematic introductions to the advanced subjects. Among these republications the collected edition of Cayley's works, now in course of publication by the University of Cambridge, is deserving of especial notice. By undertaking this great work, not only in the lifetime of its author, but while in the full vigour of his powers, the University has secured the inestimable advantage of his own editorship, and thus, under the very best auspices, the world is now being placed in full possession of this grand series of memoirs, which already cover a period of nearly fifty years.

Although it may not be possible to contemplate the actual position of pure mathematics in this country with any great amount of enthusiasm, we may yet feel some satisfaction in reflecting that there is more cause for congratulation at present than there has been at any time in the last hundred and fifty years, and that we are far removed from the state of affairs which existed before the days of Cayley and Sylvester. Unfortunately, we cannot point with pride to any distinct school of the pure sciences corresponding to the Cambridge school of mathematical physics, and I am afraid that the old saying that we have generals without armies is as true as ever. For this there is no immediate remedy; a school must grow up gradually of itself, as the study of mathematical physics has grown up at Cambridge. I certainly should not wish, even if it were possible, to obtain more recruits for the pure sciences at the expense of the applied, nor do I desire to see the system of instruction which has found favour in this country so modified that pure mathematics could be carried on by narrow specialists. I should be sorry, for example, that a student, after learning algebra and differential calculus, should pass directly to the theory of curves, and devote himself to research in this field without ever having acquired a general knowledge of other branches of mathematics or of any of its applications. Every person who proposes to engage in mathematical research should be equipped at starting upon his career with some knowledge of at least all the subjects included in the first part of the mathematical tripos. From what I have said in an earlier portion of this address it may be inferred that, from the point of view of the pure mathematician, I think that the course of study, and some of the text-books, are capable of improvement; but I am satisfied that a general mathematical training such as the tripos requires is of the greatest possible value to every student, and that without it he cannot even make a good decision as to the class of subjects to which he is likely to devote his labour with the best effect. If the student were brought by the shortest possible route to the frontier of one of the subjects, where a fruitful field of research was pointed out to him, there is no doubt that the amount of mathematical literature produced might be greatly increased; but I am sure that the advantage to science would not be proportional to this increased amount. I am convinced that no one should devote himself to the abstract sciences unless he feels strongly drawn to them by his tastes. These subjects are treated by means of a powerful symbolic language, and it is the business of the investigator to discriminate between equations and formulæ which represent valuable facts in nature, and those which are merely symbolic relations, deducible from others that are more fundamental, and having no special significance in the subject itself. The mathematician requires tact and good taste at every step of his work, and he has to learn to trust to his own instinct to distinguish between what is really worthy of his efforts and what is not; he must take care not to be the slave of his symbols, but always to have before his mind the realities which they merely serve to express. For these and other reasons it seems to me of the highest importance that a mathematician should be trained in no narrow school; a wide course of reading in the first few years of his mathematical study cannot fail to influence for good the character of the whole of his subsequent work.

Before leaving this part of my subject I should like to say a few words upon the subject of accuracy of form in the presentation of mathematical results. In other branches of science, where quick publication seems to be so much desired, there may possibly be some excuse for giving to the world slovenly or ill-digested work, but there is no such excuse in mathematics. The form ought to be as perfect as the substance and the demonstrations as rigorous as those of Euclid. The mathematician has to deal with the most exact facts of nature, and he should spare no effort to render his interpretation worthy of his subject, and to give to his work its highest degree of perfection. '*Pauca sed matura*' was Gauss's motto.

The Universities are the natural home of mathematics, and to them we chiefly owe its cultivation and encouragement. There is, however, one other much younger body whose services to our science should not be passed over in any survey of its present state—I mean the London Mathematical Society. Twenty-five years ago, upon its foundation, I think the most sanguine mathematician would scarcely have ventured to predict that it would so soon take the position that it has among the scientific institutions of the world. The continuous interest taken by its members in its meetings, and the number and value of the papers published by it, show how steadily the flame of mathematical inquiry is burning among us. I do not presume to assert that the interest taken in the pure sciences can be regarded as an index of the energy and power of a nation, but it is certain that mathematical research flourishes only in a vigorous community. The search after abstract truth for its own sake, without the smallest thought of practical application or return in any form, and the yearning desire to explore the unknown, are signs of the vitality of a people, which are among the first to disappear when decay begins.

In conclusion, I will refer in some detail to one special subject—the Theory of Numbers. It is much to be regretted that this great theory, perhaps the greatest and most perfect of all the mathematical theories, should have been so little cultivated in this country, and that no portion of it should ever have been included in an ordinary course of mathematical study. It may be said to date from the year 1801, when Gauss published his 'Disquisitiones Arithmeticæ,' so that it is nearly thirty years older than the Theory of Elliptic Functions, to which we may assign the date 1829, the year in which Jacobi's 'Fundamenta Nova' appeared. But the latter theory has already found a congenial home among us, while the former is nowhere systematically studied, and is still without a text-book. The chapters in books upon Algebra which bear the title 'Theory of Numbers' give a misleading idea of the nature of the subject, the results there given being mainly introductory lemmas of the simplest kind. The theory has nothing to do with arithmetic in the ordinary sense of the word, or numerical tables, or the representation of numbers by figures in the decimal system or otherwise. All its results are actual truths of the most fundamental kind, which must exist *in rerum naturâ*. Its principal branches are the theory of forms and the so-called complex theories. Such a proposition as that every prime number, which when divided by 4 leaves remainder 1, can always be expressed as the sum of two squares, and that this can be done in one way only, affords a good example of a very simple result in the theory of forms. It is entirely independent of any method of representing numbers, and merely asserts that if we have 5, 13, 17, 29, &c., things—let us say marbles, to fix the ideas—we can always succeed in so arranging them as to form them into two squares, and that for each number we can do this in but one way. Simple as such a theorem is to enunciate and comprehend, the demonstration is far from easy. This is characteristic of the whole subject; simple propositions, which we can easily discover by trial, and of the universal truth of which we can feel but little doubt, require for their demonstration a refined and intricate analysis, founded upon the most difficult and imaginative conceptions which mathematics has as yet attained to in its struggles to grapple with the actual problems of the worlds of thought and matter.

The theory of quantity consists of two distinct branches—one relating to discrete quantity and the other to continuous quantity. To the latter branch belong algebra and all the ordinary subjects of pure mathematics; the former bears the name of the theory of numbers. Its truths are of the most absolute kind, involving only the notions of number and arrangement; in fact, if we imagine all the exact sciences ranged in order, it naturally takes its place at one end of the series. Different sciences appeal to different intellects with very different force, but there are some minds over which the absolute character of the fundamental truths that belong to this theory and the absolute precision of its methods exercise the strongest fascination, and excite an interest which neither the truths of geometry nor the most important discoveries depending upon the constitution of matter are capable of producing.

Many of the greatest masters of the mathematical sciences were first attracted to mathematical inquiry by problems relating to numbers, and no one can glance at the periodicals of the present day which contain questions for solution without noticing how singular a charm such problems still continue to exert. This interest in numbers seems implanted in the human mind, and it is a pity that it should not have freer scope in this country. The methods of the theory of numbers are peculiar to itself, and are not readily acquired by a student whose mind has for years been familiarised with the very different treatment which is appropriate to the theory of continuous magnitude; it is therefore extremely desirable that some portion of the theory should be included in the ordinary course of mathematical instruction at our Universities. From the moment that Gauss, in his wonderful treatise of 1801, laid down the true lines of the theory, it entered upon a new day, and no one is likely to be able to do useful work in any part of the subject who is unacquainted with the principles and conceptions with which he endowed it.

Undoubtedly the subject is a difficult and intricate one even in its elementary parts, but there can be but little doubt that when the processes which are now only read by specialists on their way to the border become more generally known and studied, they will be found to admit of great simplification. It is in fact a territory where there is quite as much scope for the mathematician in simplifying what has been already won as in securing new conquests. I hope that the apathy of so many years may lead to a splendid awakening in this country, and that our past neglect of this most beautiful theory may be atoned for in the future by special devotion and appreciation.

The following Reports and Papers were read:—

1. *Report of the Committee on Electro-optics.*—See Reports, p. 144.

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2. *Notes on High Vacua.*[1] *By* J. SWINBURNE.

I.

A form of Geissler pump is described, in which the head of the pump delivers into an exhausted chamber, whose valve is opened automatically so that there is no back pressure due to small condensations of air or vapours.

II.

Experiments with two M'Leod gauges were made to find the tension of mercury vapour. Roughly, the pressure is about fifty-one millionths of an atmosphere, so that a mercury pump cannot produce vacua of one millionth, or one three-hundredth of a millionth, as commonly supposed.

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3. *On the Use of the Lantern in Class-room Work.* *By* Professor ARCH. BARR, *D.Sc.*, and Professor W. STROUD, *D.Sc.*

After referring to the advantages of lantern illustrations as compared with diagrams for class lectures, the authors described arrangements whereby the lantern may be used in partially lighted rooms during the daytime, and in the evening without diminishing the ordinary illumination. In these cases the lantern-screen is placed so that no direct light falls upon it. The lantern is placed on the lecture-table and operated by the lecturer.

The authors described a simple and convenient form of lantern to be used for horizontal or vertical projection. When using vertical projection for exhibiting lantern slides, the slides are seen by the lecturer in their proper aspect (*i.e.*, not inverted nor turned right for left), so that any details may be readily indicated by a small pointer on the slide itself. By using a finely ground and oiled glass-plate in place of the lantern slide, the lecturer may write or sketch upon it instead of on the blackboard.

An apparatus was exhibited for the preparation of lantern slides in large numbers from illustrations in books, periodicals, &c. This consists of a book-holder having provision for enabling the operator at once to set the picture centrally opposite the camera. A carriage, movable along a railway, supports the camera by a mechanism which permits it to be adjusted to any desired height, but constrains it so that it is always horizontal and properly directed. A scale upon the railway and upon the base of the camera graduated in accordance with the size of the illustrations to be photographed enables the operator at once to set the camera at the proper distance from the picture, and to focus it; thus, if the picture be 15 inches long the carriage is moved to the graduation 15 on the railway and the back of the camera to a graduation 15 on the base. The height of the camera also is adjusted by a scale in accordance with the reading of a scale placed on the book-holder at the side of the picture. By these means the camera is completely set and focussed without the use of a ground-glass screen. The picture is illuminated by gas or other artificial light.

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[1] *Electrician*, Sept. 5, 1890.

4. *On Refraction and Dispersion in certain Metals.* *By* H. E. J. G. DU BOIS and H. RUBENS.[1]

Kundt's method of experiment with very thin electrolytic metal biprisms was used in this investigation. In the first place measurements were made on red light obliquely transmitted; from the deviations thus observed a process of integration, entirely independent of any particular optical theory, led to the empirical law connecting i and i_m; these symbols denoting the inclinations of the wave-front in the air and the metal respectively to their common bounding-surface. Secondly, the dispersion was determined with all possible care, using four kinds of light defined by spectral lines. The following is a synopsis of the results:—

I. Light, on passing from Fe, Co, and Ni (probably also from a number of other metals) into air, begins by following Snellius' sine law for small angles of emission.

II. The refractive index of such metals is mathematically defined as $\lim_{i=o} (\sin i / \sin i_m)$.

III. The actual metals deviate from ideal substances, supposed to possess the index thus defined in the following sense: to a given i_m corresponds a *greater* value of i, or to a given i a *lesser* value of i .

The differences become more marked the greater the inclination, and are given empirically by the authors' experiments; for the three metals they decrease in the order Ni, Co, Fe.

IV. The anomalous dispersion is illustrated by the following table of refractive indices:—

Line	Li. *a*	D	F	G
Iron	3·12	2·72	2·43	2·05
Cobalt	3·22	2·76	2·39	2·10
Nickel	2·04	1·84	1·71	1·54

5. *On an Illustration of Contact Electricity presented by the Multicellular Electrometer.* *By* Sir WILLIAM THOMSON, *D.C.L., LL.D., F.R.S.*

In the multicellular electrometer, the force between the aluminium needles and the brass cells is modified by the 'contact-electricity' difference between polished brass and polished aluminium. In the trial instruments made up to about a year ago, the result was scarcely perceptible; probably because care had not in them been bestowed to give high polish to the metallic surfaces.

In the instrument as now made, differences of from two-tenths to three-tenths of a volt are found; averaging about $\frac{1}{4}$ of a volt.

The force by which $\frac{1}{4}$ of a volt of difference of potential, on a difference of 100 volts, bears to the force by which the same difference could be shown with the two metals in metallic connection, the ratio of $(100+\frac{1}{4})^2-100^2$ to $(\frac{1}{4})^2$ or of 800 to 1. Thus the use of the multicellular electrometer gives a new and very interesting direct proof of Volta's contact electricity.

Some careful observations in Major Cardew's new standardising laboratory of the Board of Trade, made by Mr. Rennie at frequent intervals during the last six weeks, have given doubled differences of from ·65 to ·5, seeming to show a slight tendency to decrease with time.

6. *On Defective Colour Vision.* *By* Lord RAYLEIGH, *Sec.R.S.*

The existence of a defect is probably most easily detected in the first instance by Holmgren's wool test; but this method does not decide whether the vision is truly dichromic. For this purpose we may fall back upon Maxwell's colour discs.

[1] *Berlin Acad. Sitzungsber.* July 24, 1890.

Dichromic vision allows a match between any four colours, of which black may be one. Thus we may find 64 green + 36 blue = 61 black + 39 white, a neutral matched by a green-blue. But this is apparently not the most searching test. The above match was in fact made by an observer whose vision I have reason to think is not truly dichromic, for he was unable to make a match among the four colours red, green, blue, black. The nearest approach appeared to be 100 red = 8 green + 7 blue + 85 black, but was pronounced far from satisfactory. An observer with dichromic vision, present at the same time, made without difficulty 82 red + 18 blue = 22 green + 78 black, a bright crimson against a very dark green.

It would usually be very unsafe to conclude that a colour-blind person is incapable of making a match because he thinks himself so. But, in the present instance, repeated trials led to the same result, while other matches, almost equally forced in my estimation, were effected without special difficulty. It looked as though the third colour sensation, presumably red, was defective, but not absolutely missing. When a large amount of white was present, matches could be made in spite of considerable differences in the red component, but when red light was nearly isolated its distinctive character became apparent.

This view of the matter was confirmed by experiments with my colour box, in which, by means of double refraction, a mixture of spectral red and green can be exhibited in juxtaposition with spectral yellow ('Nature,' Nov. 17, 1881). A match to normal vision requires, of course, that (by rotation of the nicol) the red and green should be mixed in the right proportions; and secondly, that (by adjustment of gas) the brightness of the spectral yellow should be brought to the right point. An observer whose vision is dichromic does not require the first adjustment; any mixture of red and green, or even the red and green unmixed, can be matched against the yellow. In the present case, however, although the green could be matched satisfactorily against the yellow, the red could not. The construction of the instrument allowed the point to be investigated at which the match began to fail. Pure green corresponding to 0, and pure red to 25, the match with yellow began to fail when the setting reached about 17. Normal vision required a setting of about 11.

Truly dichromic vision may be thus exhibited in a diagram. If we take red, green, blue, as angular points of a triangle, there is a point upon the plane which represents darkness. Any colours which lie upon a line through this point differ only in brightness. Maxwell determined the point by comparison of colour-blind matches with his own normal ones. It seems preferable to use the colour-blind matches only, as may be done as follows: From the match between red, green, blue, and black, the position of black on the diagram may be at once determined, and for most purposes would represent darkness sufficiently well. A match between white and the principal colours will then fix its position relatively to the fundamental points. A line joining black and white is the *neutral* line; all colours that lie on one side of it are warm, like yellow; all that lie upon the other side are cold. The point representing darkness will lie upon the neutral line and a little beyond black. The diagram sketched depends upon the following matches obtained from an observer, whom Holmgren would call green-blind:—

Red	Green	Blue	Black	White	Yellow
−82·0	+21·8	−18·0	+78·2	0	0
+57·2	−100	+4·8	0	+38·0	0
0	+96·0	+4·0	−53·0	−47·0	0
−100	0	+5·0	+78·7	0	+16·3

7. *On some New Vacuum Joints and Taps.* *By* W. A. Shenstone.

8. *On the General Theory of Ventilation, with some Applications.* *By* W. N. Shaw, *M.A.*

For successful ventilation two primary conditions must be satisfied: (1) there must be a sufficient supply of air; (2) the entering air must be suitably distributed in the ventilated space. These two conditions suggest corresponding divisions of the subject. That part dealing with the amount of air supplied is referred to by the term 'general circulation,' while the other part, which is concerned with distribution, may be said to deal with 'local circulation.' In this paper the general circulation alone is discussed. The motion of the air is supposed to be 'steady.'

If numbers are used, the units supposed to be employed are the foot, pound, and second respectively.

The process of ventilation is treated as the flow of air through a duct of more or less complicated shape. For an ordinary room with open fireplace the parts of the complete duct are (1) the inlet openings (often indefinite), (2) the room itself, and (3) the chimney.

The motion of air upon which the ventilation depends is due to the existence of a 'head,' which is numerically expressed by the work done in driving unit mass of air through the whole length of the duct. If the work is measured in foot-pounds and the mass in pounds, the head is expressed as a number of feet in height of air, and therefore corresponds to a pressure-difference that can be expressed as difference of water-level or lbs.-weight per square foot.

The head may be due to one or more of the following causes:—

(1) Wind impinging directly upon an opening;
(2) Wind blowing across an opening;
(3) Ventilating fans and blowing machines;
(4) High temperature in a vertical shaft.

The numerical value of the head in feet of air can be calculated from certain data for each of the four causes.

The volume of air flowing in the unit of time across any imagined cross-section of the duct can be expressed in cubic-feet per second, and is called the 'flow.'

The following *general laws of ventilation* are established:—

Law I. *Continuity of flow.*—The mass of air flowing per second across all transverse sections of the duct is the same. Hence the flow across any section is inversely proportional to the density of air at that section. If the variations of density are negligeable we may say that the *flow* is the same across every section. It would be strictly so if the air were an incompressible fluid.

Law II. *Definition of resistance and of equivalent orifice.*—For any duct the ratio of the head to the square of the flow is a constant which depends on the shape and dimensions of the duct, and is called the 'resistance of the duct.' Two ducts may give the same flow for the same head, although they may be of widely different shapes; thus every duct, no matter how complicated, is equivalent to and can be represented by an orifice of suitable size in a thin plate. The thin-plate orifice equivalent to a duct is called (following M. Murgue) the 'equivalent orifice of the duct.' If R be the resistance of a duct, and a the area of its equivalent orifice, $R = 1/27a^2$ approximately. [Foot, lb. sec. units.]

The resistance of a duct of known form can be calculated from its dimensions; bends, gratings, &c., increase its resistance, and can be allowed for, as shown in Péclet's *Traité de la Chaleur*.

Law III. *Ducts in series.*—If a duct is formed by connecting 'in series' two or more separate ducts, its resistance is the sum of the resistances of the several components, provided that two ducts are only understood to be connected when the opposed ends of each communicate with an ample air-space (otherwise closed) separating them.

The head for the complete circulation may be regarded as the sum of the heads for each component duct.

Law IV. *Parallel ducts.*—When ducts are arranged parallel, or in 'multiple arc' (as when a number of openings are made side by side in one wall), they are equivalent to a resultant duct whose equivalent orifice is equal to the sum of the equivalent orifices of the components.

These Laws are applied to furnish solutions (making certain assumptions) to the following problems:—

1. To determine from measurements of the flow the equivalent orifice of a duct—*e.g.*, a chimney.

2. To determine the equivalent orifice of the casual inlets (chinks in doors and windows) of a room.

3. To calculate the amount of air that will enter by an open window into an otherwise closed room, maintained at a known difference of temperature above that of the outside air.

4. To calculate the conditions under which a straight vertical chimney is liable to act as inlet and outlet simultaneously.

5. To calculate the condition under which the outward flow through an extract-ventilator is liable to be reversed in a room with an open fire.

6. To determine the conditions necessary for the isolation of one circulation from another—*e.g.*, to prevent the air of one room passing into an adjoining room.

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9. *Account of Experiments to determine the Variations in Size of Drops with the Interval between the Fall of each.* *By* W. Binnie, *B.A.*

These experiments were carried out while the author was engaged in constructing a self-registering rain-gauge, designed so as to count each drop as it fell from the funnel. Thus, the correct working of the gauge depended on the assumption that drops falling from a tube remained constant in size under varying conditions. This assumption proved partially incorrect, as it was found that the size of the drops varied, within certain limits, with the interval of time between the fall of each; but, as will be seen, by choosing the funnel of such a diameter as not to discharge drops at more than a certain speed, error from this cause could be eliminated. The variations which took place with various tubes of different diameter, also with a drop falling from a plate, were shown in a diagram; the horizontal scale representing the interval in seconds, the vertical the size of drops in hundredths of one cubic centimetre. Similar variations took place in all the tubes. When the interval remained constant, the size of the drop was constant. When the interval between the fall of each drop was greater than ten seconds or thereabouts the size of the drop became constant, as shown by the curve in each case becoming parallel with the horizontal scale. About this point a variation began to set in when the intervals between the fall of each drop grew shorter, and this variation rapidly increased, until, when the interval became nothing, or, in other words, the drops formed a stream, a drop of infinite size, the curves would become asymptotic to the vertical scale line. The curves show the variations which take place between these two extreme cases. Drawings of the drops seemed to indicate that, with intervals shorter than ten seconds or thereabouts, small accessory drops became split off together with one main drop, so that the variation might be due to the fact that this accessory detachment became larger relatively to the main drop as the interval became shorter. The theoretical size of the drop for each tube is also plotted on the diagram, and is in each case considerably above the value of the drop when it became constant. This might be due to the tubes not being perfectly clean.

FRIDAY, SEPTEMBER 5.

The following Papers were read:—

1. *Recent Determinations of the Absolute Resistance of Mercury.* *By* R. T. Glazebrook, *M.A.*, *F.R.S.*

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2. *Suggestions towards a Determination of the Ohm.*[1] *By* Professor J. VIRIAMU JONES, *M.A.*

The main suggestions offered for consideration are—

1. That the time is ripe for a new determination of the ohm that shall be final for the practical purposes of the electrical engineer.

2. That such a determination may be made by the method of Lorenz, the specific resistance of mercury being obtained directly in absolute measure by the differential method described.

3. That the standard coil used in the determination should consist of a single layer of wire, the coefficient of mutual induction of the coil and disc circumference being calculated by a new formula (communicated by the author to the Physical Society in November 1888, 'Phil. Mag.' January 1889).

Measurements have been made on the lines indicated in the Physical Laboratory of the University College at Cardiff. Five complete sets of observations were taken in the spring of this year, with the following results for the specific resistance of mercury at 0° C.:—

(1)	94,103	absolute units
(2)	94,074	" "
(3)	94,093	" "
(4)	94,045	" "
(5)	94,021	" "
Mean	94,067 ± 10	(probable error).

The result may be otherwise expressed by saying that the ohm is equal to the resistance of a column of mercury of one square millimetre sectional area, and 106·307 centimetres long, the probable error being ± 0·012.

[These Papers were followed by a Discussion on Electrical Units.]

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3. *On Alternate Currents in Parallel Conductors of Homogeneous or Heterogeneous Substance.* *By* Sir WILLIAM THOMSON, *D.C.L., LL.D., F.R.S.*

This Paper consists of a description of some of the results of a full mathematical investigation of the subject, which the author hopes to communicate to the 'Philosophical Magazine' for an early number:—

1. Two or more straight parallel conductors, supposed for simplicity to be infinitely long, have alternating currents maintained in them by an alternate-current dynamo or other electro-motive agent applied to one set of their ends at so great a distance from the portion investigated that in it the currents are not sensibly deviated from parallel straight lines. The other sets of ends may, indifferently in respect to our present problem, be either all connected together without resistance, or through resistances, or through electro-motive agents. All that we are concerned with at present is, that the conductors we consider form closed circuits, or one closed circuit, and that therefore the total quantities of electricity per unit of time at any instant traversing the normal sections in opposite directions are equal.

2. We suppose the period of the alternation to be very great in comparison with the time taken by light to traverse a distance equal to the greatest diameter of cross-section of our whole group of conductors. This supposition is implied in the previous assumption of parallel rectilinearity of the electric stream lines, and of equality of the quantities of electricity traversing, in opposite directions, the several areas of a normal section.

3. We further suppose that the length of our conductors and their effective

[1] Published *in extenso* in the *Electrician*, vol. xxv. No. 644.

ohmic resistances are so moderate[1] that the quantities of electricity deposited on and removed from their boundaries to supply the electrostatic forces along the conductors required for producing the alternations of the currents, are negligeable in comparison with the total quantity flowing in either direction in the half period. This supposition excludes important practical problems of telegraphy and telephony, the problem of long submarine cables, for instance; but it includes the problem of electric lighting by alternating currents transmitted at high tension through considerable distances; as, for example, from Deptford to London.

4. The general investigation includes as readily any number of separate circuits of parallel conductors as a single circuit, but, for simplicity in describing results, I suppose our system of conductors to be so joined at their ends as to constitute a single simple circuit of two parallel conductors.[2] It may be either two parallel conductors or one conductor, one of which may or may not surround the other, as shown in Figs. 1 and 2, representing cross-sections. Each conductor may be single, as in Figs. 1 and 2, or either may be multiple parallels.

FIG. 1.

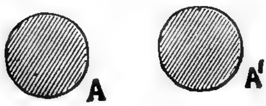
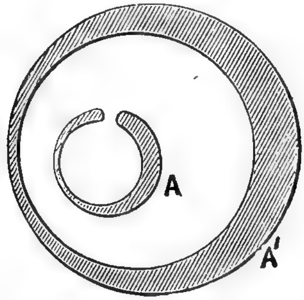


FIG. 2.



5. We suppose each conductor to be homogeneous in substance, and in cross-section from end to end, but not necessarily homogeneous in different parts of the cross-section. Thus the two conductors, or the different parts of either, may be of different metals, or either conductor or any part of either conductor may consist of two metals (as iron and copper, or iron and lead) laid parallel and soldered together.

6. We shall call A and A′ the cross-sectional areas or groups of areas of the two conductors respectively of the other. All the different portions of A are connected metallically at their two ends, and are thus all of them at one potential at one end and another potential at the other end; and similarly for A′. The homogeneousness of the material and of the cross-sections along the length of the conductors and the uniformity of the total currents assumed in section 3, implies that all the different parts of A in one cross-sectional plane are at one potential, even though A consist of mutually isolated parts, or A′ consist of isolated parts. If, as

[1] The circumstances in which this condition is fulfilled may be usefully illustrated by considering the important practical cases of submarine cables, and of metallic circuits of two parallel wires insulated at a distance anything less than a few hundred times their diameter. For all these cases the numeric expressing the electrostatic capacity of either conductor per unit length (the other supposed for the moment to be at zero potential) is between 2 and 0·1, and for our present rough comparison may be regarded as moderate in comparison with unity. On this supposition the condition of the text requires for fulfilment that the mean proportional between the velocity which expresses in electro-magnetic measure the resistance of one of the conductors and the velocity of a body travelling the length of the conductor in a time equal to half the period of alternation, shall be exceedingly small in comparison with the velocity of light.

[2] The case of a single circuit made up of parallel conductors, so joined at their ends that to travel once round it we must go and come two or three or more times along separate conductors, joined by their ends in series, so as to make one circuit, is specially considered in my Paper on 'Anti-Effective Copper in Parallel or in Coiled Conductors for Alternating Currents,' p. 736.

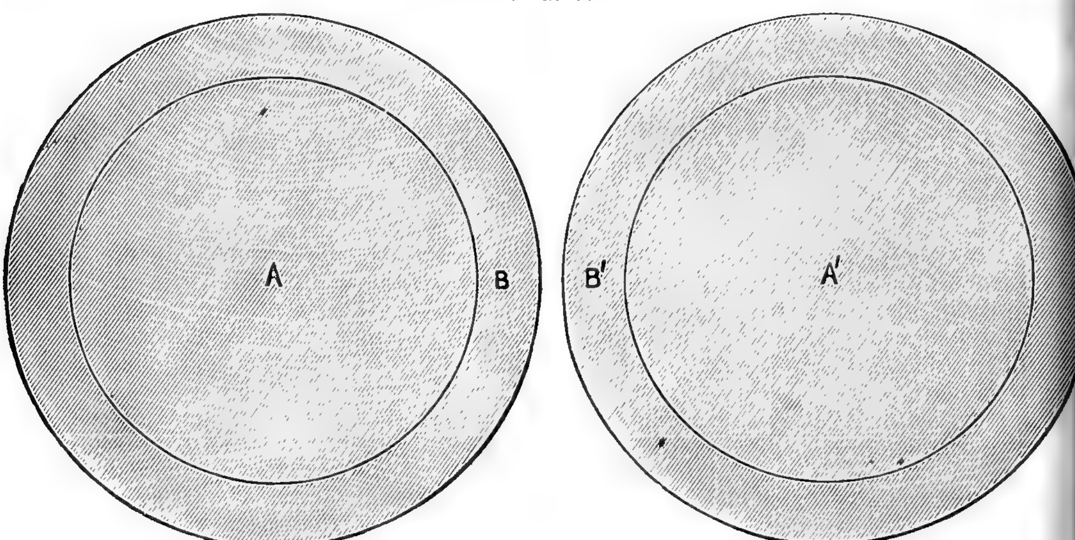
in Figs. 1 and 2, all the parts of A are in mutual metallic connection, and all the parts of A′ are in mutual metallic connection, this would entail uniformity of potential through A, and uniformity of potential through A′, even without the limitation of our subject laid down in section 3.

7. The following are some of the most noteworthy results of the full mathematical treatment of the subject:—

I. When the period of alternation is large in comparison with 400 times the square of the greatest thickness or diameter of any of the conductors, multiplied by its magnetic permeability, and divided by its electric resistivity, the current intensity is distributed through each conductor inversely as the electric resistivity; the phase of alternation of the current is the same as the phase of the electromotive force; and the current across every infinitesimal area of the cross-section is calculated, according to the electro-motive force at each instant, by simple application of Ohm's law.

II. When the period is very small in comparison with 400 times the square of the smallest thickness, or diameter of any of the conductors, multiplied by its magnetic permeability and divided by its electric resistivity, the current is confined to an exceedingly thin surface-stratum of the conductors. The thickness of this

FIG. 3.



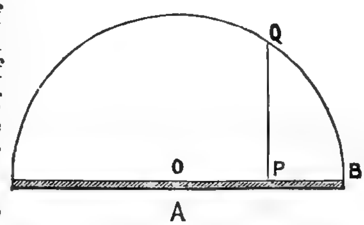
stratum is directly as the square root of the quotient of resistivity, divided by magnetic permeability, of the substance in different parts of the surface. The total quantity of the current per unit breadth of the surface independent of the material, and, except in such cases as those referred to at the end of II. below, varies in each cross-section in simple proportion to the electric surface density of the static electrification induced by the electro-motive force applied between the extremities for maintaining the current. The distribution of this electric density is similar in all cross-sections, but its absolute magnitude at corresponding points of the cross-section varies along the length of the conductor in simple proportion to the difference of electric potential between A and A′, and is zero at one end, in the particular case in which the conductors are connected through zero resistance at one end, while the electro-motive force is applied by an alternate current dynamo at the other end. On the other hand, the surface distribution of electric current is uniform throughout the whole length of the conductors, and it is only its distribution in different parts of the cross-section that varies as the electric density.

The proportionality of surface intensity of the current to electric density, asserted above, fails clearly in any case in which the circumstances are such that the distance we must travel along the surface to find a sensible difference in electric density is not very great in comparison with the thickness of the current-stratum. Such a case is represented in Fig. 3, which is drawn to scale for alternate currents of period $\frac{1}{80}$ of a second in round rods of copper of six centimetres diameter. The spaces between the outer circular boundaries and the inner fine circles indicate what I have called the ohmic thickness,[1] being ·714 of a centimetre for copper of resistivity 1611 square centimetres per second. The full solution for such a case as that represented in Fig. 3 belongs to the large class of cases intermediate between I. and II., and could only be arrived at by a kind of transcendent mathematics not hitherto worked. But, without working it out, it is easy to see how the time-maximum intensity of the current will diminish inwards from the surface, and will be, at any point of either of the inner fine circles, about one-half or one-third of what it is at the nearest point of the boundary surface; and that at points in the surface, distant from B B′ by one-half or one or two times the ohmic thickness, the current intensity will be much smaller than it is at B and B′.

III. In Case I. the heat generated per unit of time, per unit of volume, in different parts of the conductors, is inversely as the electric resistivity of the substance, and directly as the square of the total strength of current at any instant. In Case II. the time-average of the heat generated per unit of time, per unit of area of the current stratum, is as the time-average of the square of the quantity of current per unit breadth, multiplied by the square root of the product of the electric resistivity into the magnetic permeability.

IV. Example of III.: Let the conductor A be a thin flat bar, as shown in the diagram (Fig. 4), A′ being a tube surrounding A, or another flat bar like A, or a conductor of any form whatever, provided only that its shortest distance from A is a considerable multiple of the breadth of A. The thickness of A must be sufficiently great to satisfy the condition of II., and its breadth must be a large multiple of its thickness. (For copper carrying alternating currents of frequency 80 periods per second, these conditions will be practically fulfilled by a flat bar of 4 cms. thickness and 30 or 40 cms. breadth.) The current in it is chiefly confined to two strata, extending to small distances inwards from its two sides. (For copper and frequency 80 periods per second, the time-maximum of intensity of the current at the surface will be about ϵ^2, or 7·4 times what it is at a distance 1·43 cm. in from the surface.) The quantity of current per unit breadth, or, as we may call it for brevity, the surface-density of the current in each stratum, is determined by the well-known solution of the problem of finding the surface-electric-density of an electrified ellipsoid of conductive material undisturbed by any other electrified body. The case we have to consider is that of an ellipsoid whose longest diameter is infinite, medium diameter the breadth of our flat conductor, and least diameter infinitely small. In this case the electric density varies inversely as $\sqrt{(OB^2 - OP^2)}$. The graphic construction in the drawing shows $PQ = \sqrt{(OB^2 - OP^2)}$, and we conclude that the time-maximum of the surface-density of the current varies inversely as PQ. The infinity, which in the electric problem we find for electric density of the ideal conductor, is obviated for the electric current problem by the proper consideration of the rectangular corners or the rounded edge (as the case may be) of our copper bar, which, though exceedingly interesting, is not included in the present communication. Suffice it to say that there will be no infinities, even if the corners be true mathematical angles.

FIG. 4.



V. Example of Cases I. and II.: Let A consist of three circular wires, C, L, and I, of copper, lead, and iron respectively. In Case I. the quantities of the whole current they will carry, and the quantities of heat generated per unit of time in them, will be inversely as their resistivities. In Case II., if the centres of the three circular cross-sections form an equilateral triangle, the quantities of heat generated in them will be directly as the square roots of the resistivities for C and L; and for I would be as the square root of the product of the resistivity into the magnetic permeability, if the magnetic permeability were constant and the viscous

[1] *Collected Papers*, vol. iii. Art. cii. section 35.

or frictional resistance to change of magnetism nothing for the iron in the actual circumstances. This last supposition is probably true approximately with a permeability of $\frac{1}{80}$ for iron or steel, according to Lord Rayleigh, if the current is so small that the greatest magnetising force acting on the iron is less than ·1 C.-G.-S.

VI. The dependence of the total quantity carried on extent of surface, according to the electrostatic problem described in II., justifies Snow Harris, and proves that those who condemned him out of Ohm's law were wrong, in respect to his advising tubes or broad plates for lightning conductors; but does not justify him in bringing them down in the interior of a ship (even through the powder magazine) instead of across the deck and down its sides, or from the masts along the rigging and down the sides to the water. The non-dependence of the total quantities of current on the material, whether iron or non-magnetic metals, seems quite in accordance with Dr. Oliver Lodge's experiments and doctrines regarding 'alternative path' and lightning conductors. The case of alternate currents is, of course, not exactly that of lightning discharges; but from it, by Fourier's methods, we infer the main conclusions of II. and V., whether the discharges be oscillatory or non-oscillatory, provided only that it be as sudden as we have reason to believe lightning discharges are.

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4. *On Anti-Effective Copper in Parallel Conductors or in Coiled Conductors for Alternate Currents.* *By* Sir WILLIAM THOMSON, *D.C.L., LL.D., F.R.S.*

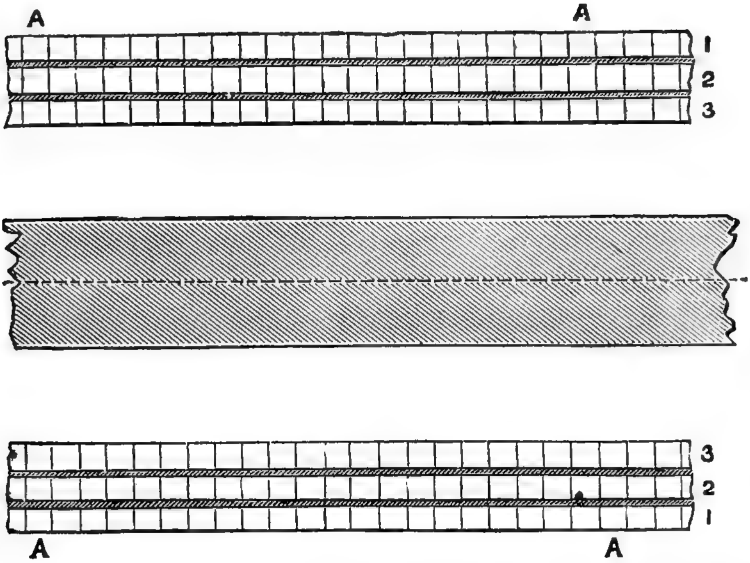
1. It is known that by making the conductors of a circuit too thick we do not get the advantage of the whole conductivity of the metal—copper, let us say—for alternate currents. When the conductor is too thick, we have in part of it comparatively ineffective copper present; but, so far as I know, it has generally been supposed that the thicker the conductor the greater will be its whole effective conductance, and that thickening it too much can never do worse than add comparatively ineffective copper to that which is most effective in conveying the current. It might, however, be expected that we could get a positive augmentation of the effective ohmic resistance, because we know that the presence of copper in the neighbourhood of a circuit carrying alternate currents causes a virtual increase of the apparent ohmic resistance of the circuit in virtue of the heat generated by the currents induced in it. May it not be that anti-effective influence such as is thus produced by copper not forming part of the circuit can be produced by copper actually in the circuit, if the conductor be too thick? Examining the question mathematically, I find that it must be answered in the affirmative, and that great augmentation of the effective ohmic resistance is actually produced if the conductor be too thick; especially in coils consisting of several layers of wire laid over one another in series around a cylindric or flat core, as in various forms of transformer.

2. Fig. 1 may be imagined to represent the secondary coil of a transformer consisting of solid square copper wire in three layers. For simplicity we suppose the axial length to be infinitely great, and straight; but the uniformity which this involves, and a close practical application to its simplicity, is realised in that excellent form of transformer which consists of a toroidal iron core completely covered by primary and secondary wires laid on toroidal surfaces. To simplify the mathematical work, I suppose the whole thickness of the three layers to be small in comparison with the greatest radius of curvature of the circular or flat cylindric surface on which the wire is wound, but if it is not so the solution is easily obtained, for the case of circular cylinders, in terms of the Fourier-Bessel functions. It is of no consequence for our present question what there be inside of coil No. 3, and, if we please, we may imagine there to be nothing but air; the drawing, however, indicates an iron core and a space which might be occupied by the primary coil, if a transformer is the subject; or our coil A A A A may be the primary coil of a transformer with secondary coil and core inside it, and the alternate current maintained in it by an external electro-motive agent acting in an arc between its ends outside. Our present results are applicable to all these varieties of cases

indifferently, all that is essential being that the total quantity of current be given at each instant, and be uniform throughout the whole length of the coiled conductor.

3. This last condition is secured by perfectness of insulation between all contiguous turns of the coil, unless we were considering so enormously long a coil that

FIG. 1.



the quantity of electricity required for the essential changes of static electrification would be sensible as constituting drafts from, or contributions to, the current in the coil. The consideration of static electrification, involved in the maintenance of alternate currents through a coil such as that represented in Fig. 1, is exceedingly curious and interesting; but we do not enter on it at present at all, as in all practical cases the quantities concerned are quite infinitesimal in comparison with the whole quantity flowing in one direction or the other in the half period.

4. In the drawing the section of the wires is represented as square; but this is not essential, and in practice a flat rectangular ribbon would, no doubt, for some dimensions of coils, be preferable. I assume the thickness of the insulation between the successive squares or rectangles in each layer to be infinitely small in comparison with the breadth of the rectangle; but the thickness of the insulation between successive layers, which is a matter of indifference to my calculations, may be anything; and would, in practice, naturally be, as shown in the diagram, considerably greater than the thickness of the insulation between the contiguous portions of the coil in each layer.

5. The full mathematical work which I hope to communicate to the 'Philosophical Magazine' for publication in an early number includes an investigation of the self-induction of the coil with or without anything in its interior (such as core or primary wire of a transformer); but at present I merely give results, so far as effective ohmic resistance, or generation of heat in the interior of the wire of the coil A A A A itself, is concerned, which, as said above, is independent of everything in the interior, and of the mode in which the alternating current is produced, provided only that the total amount of electricity crossing the section of the wire per unit of time be given at each instant.

6. As a preliminary to facilitate the expression of these results, it is convenient first to give a general statement of the solution of the problem of laminar diffusion of a simple harmonic variation, applied to the case of electric currents in a homogeneous conductor. Let the periodically varying magnetic force in the air or other insulating material in the neighbourhood of so small a portion, S, of the surface of a conductor that we may regard it as plane, be given. Resolve this magnetic

force into two components, one, perpendicular to S, which we may neglect, as it has no influence in connection with the currents we are to consider, the other, parallel to S, which we shall call the effective component and denote by Y. Through any point O, of S, draw three rectangular lines O X, O Y, O Z, of which O Y and O Z are in S, and O X is parallel to the direction of the effective magnetic force component Y. Let now the value of Y at time t be

$$Y = M \cos \frac{2\pi t}{T},$$

where M denotes a constant, and T the period of the alternation. The varying magnetic force Y, to whatever cause it may be due, implies currents parallel of O Z in the conductor, expressed by the formula for γ, the current intensity at distance X from the plane S, provided T be small enough to fulfil the condition stated below:—

$$\gamma = \frac{M}{\lambda\sqrt{2}} \varepsilon^{-\frac{2\pi x}{\lambda}} \cos\left(\frac{2\pi t}{T} - \frac{2\pi x}{\lambda} + \frac{1}{4}\pi\right);$$

where λ denotes what we may call the wave-length of the disturbance, and is given in terms of T, the period of the disturbance, and ρ and Π the resistivity and magnetic permeability of the substance, by the following formula:—

$$\lambda = \sqrt{\frac{T\rho}{\Pi}}.$$

For copper we have $\Pi = 1$, and $\rho = 1611$ square centimetres per second; and thus for 80 periods per second $\lambda = 4{\cdot}49$, or, say, $4\frac{1}{2}$ centimetres. In order that the formula for γ may be approximately true it is necessary, in the first place, that λ must be small in comparison with the distance we must travel in any direction in the surface of S before finding any deviation of it from the tangent plane through O comparable with λ. Secondly, for a very good approximation, λ must be so small that we may be able to travel inwards in any direction from O, through a space equal to at least twice λ, without coming to any other part of the bounding surface of the conductor. If, for example, the surface be a flat plate, this condition requires that the thickness be more than twice λ. But (because $\epsilon^{-\pi}$ is less than $\frac{1}{23}$) the formula gives a very fair approximation requiring for a half the thickness of the plate inwards from S no greater correction than about 4 per cent., even if the thickness of our plate be no greater than λ. When the thickness of the plate is less than 2 λ, we may consider waves of electric current as travelling inwards from its two sides, and being both sensible at the middle of the plate; and a complete solution of the problem is readily found by the method of images. But a direct analytical investigation, by which the proper conditions of relation to varying magnetic force on the two sides of the plate are fulfilled, is the most convenient way of fully solving the problem, and it is thus that the results given below have been obtained.

7. The smallness of the insulating space between the successive turns in each layer of our coil A A A A, and the equality of the whole current through them all, prevent any surface disturbance from being produced at the contiguous faces, and allow the problem to be treated as if, instead of a row of squares or rectangles, we had a continuous plate forming each stratum. The smallness of the thickness of this plate in comparison with the radius of the cylindric surface to which it is bent allows, as said above, the mathematical treatment for an infinite plate bounded by two parallel planes to be used without practical error. I have thus found an expression for the intensity of the current at any point in the metal of any one of the layers of a coil of one, two, three, or more layers; and have deduced from it an expression for the quantity of heat generated per unit of time, at any instant, per unit breadth in any one of the layers. I need not at present quote the former expression; the latter is as follows:—With q to denote the dynamical value of the time-average of the heat generated per unit of time at different instants of the period, per unit breadth and unit length in layer No. i, from the outside of the

coil, c^2 the time-average of the square of the total current per unit breadth, and a the thickness of the layer,

$$q = \frac{2\pi\xi\Theta c^2}{\lambda},$$

where

$$\Theta = \frac{\varepsilon^{2\theta} + 2\sin 2\theta - \varepsilon^{-2\theta}}{\varepsilon^{2\theta} - 2\cos 2\theta + \varepsilon^{-2\theta}} + 2i(i-1)\frac{\varepsilon^{\theta} - 2\sin\theta - \varepsilon^{-\theta}}{\varepsilon^{\theta} + 2\cos\theta + \varepsilon^{-\theta}}$$

and

$$\theta = \frac{2\pi a}{\lambda}.$$

8. The numerical results shown in the table have been calculated, and the accompanying graphic representation (Fig. 2) drawn for me by Mr. Magnus Maclean.

FIG. 2.

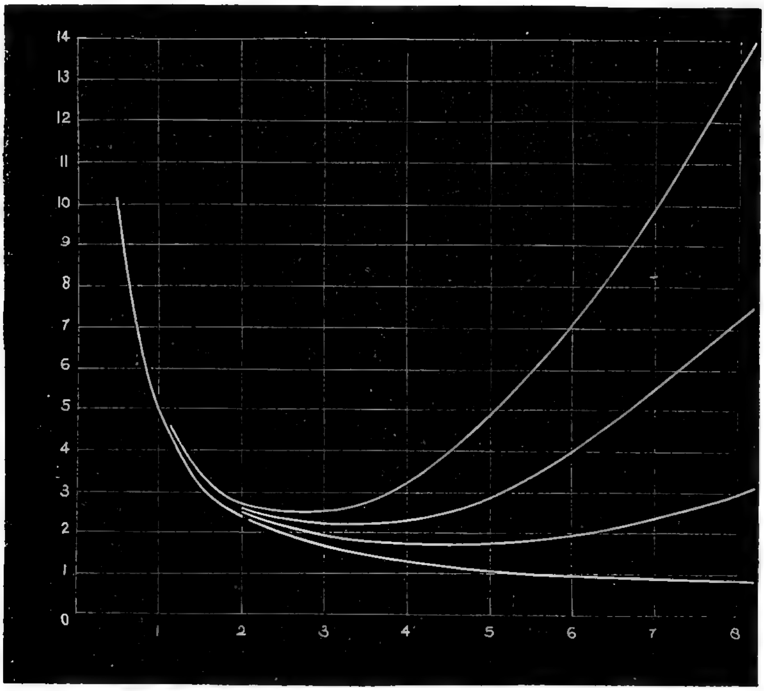


Table of Values of Θ.

$\frac{16\theta}{\pi}$	$i=1$	$i=2$	$i=3$	$i=4$
1	5·113	5·118	5·127	5·141
2	2·553	2·592	2·669	2·786
4	1·316	1·634	2·270	3·224
6	·9854	1·997	4·019	7·053
8	·9173	2·993	7·143	13·37
10	·9452	4·062	10·30	19·65
12	·9822	4·899	12·73	24·48
14	1·000	5·276	13·83	26·66
16	1·002	5·362	14·08	27·16
∞		5·000	13·00	25·00

9. We see from the tables and curves that each curve has a minimum distance from the line of abscissas, and that each comes to an horizontal asymptote, parallel to the line of abscissas, for $\theta=\infty$. By looking at the formula we see that there is, in fact, an infinite succession of minimums and maximums in the expression for Θ; but it is only the first minimum and following maximum that occur within the range of variation of Θ, which we regard as sensible. In the case of $i=1$ the formula gives $\theta=\frac{1}{2}\pi$ for the first minimum. The curves show for the cases of $i=2$, 3, 4, respectively the first minimum at $\frac{16\theta}{\pi}=4\frac{1}{2}$, 3, and 2·6 respectively. The thickness which corresponds to $\theta=\pi$ is the half-wave length of the electric disturbance, which, as we have seen, is for copper 2·244 centimetres when the frequency of the alternations is 80 periods per second; and for this case, therefore, the thicknesses that give minimum generation of heat in the first, second, third, and fourth layers are respectively 11·22, 6·31, 4·21, and 3·65 millimetres. Anything more of continuous copper than these thicknesses in any of the layers would be not merely ineffective or comparatively ineffective, but would be positively anti-effective. Even with so small a thickness as 2·8 millimetres, for copper and frequency 80, line 2 of the table (corresponding to a sixteenth of the wave length) shows, in the first, second, third, and fourth layers, losses of 0·3 per cent., 2 per cent., 5 per cent., and 10 per cent. in excess of that due to the true ohmic resistance of the copper were it all effective. When the size chosen for the transformer and the amount of output required of it are such that a thickness of $2\frac{1}{2}$ millimetres in the direction perpendicular to the layers is insufficient, a remedy is to be had by using braided wire, or twisted strand, with slight insulation of varnish or whitewash, crushed or rolled into rectangular or square form of the desired thickness and breadth. A very slight resistance between the different wires thus crushed together would suffice to cause the current to run nearly enough full bore to do away with any sensible loss from the cause which forms the subject of this communication.

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5. *The Molecular Theory of Induced Magnetism (with exhibition of a Model).* *By* Professor J. A. Ewing, *F.R.S.*

In applying Weber's theory of molecular magnets to explain the phenomena of induced magnetism, it is not necessary to assume that the molecules are subject to any other directional constraint than is supplied by their mutual magnetic forces. This is demonstrated by means of a model consisting of a group of small permanent magnets, each free to turn about a fixed centre. The manner in which the configuration of the group changes when an external magnetic field is imposed or varied in any way is shown, by means of the model, to correspond exactly with the known character of the corresponding changes of induced magnetism in iron and other susceptible metals. Hysteresis, of which magnetic retentiveness is one manifestation, occurs in virtue of the movements of the molecules through conditions of instability; these movements, being mechanically irreversible, involve dissipation of energy. Such movements occur when metals are subjected to cyclic strains, apart from the existence of magnetisation. The author has developed his views in a paper communicated to the Royal Society ('Proceedings,' June 19, 1890) and republished in the 'Philosophical Magazine' for September 1890. The considerations adduced there lead to the following conclusions:—

1. That in considering the magnetisation of iron and other magnetic metals to be caused by the turning of permanent molecular magnets, we may look simply to the magnetic forces which the molecular magnets exert on one another as the cause of their directional stability. There is no need to suppose the existence of any quasi-elastic directing force or of any quasi-frictional resistance to rotation.

2. That the intermolecular magnetic forces are sufficient to account for all the general characteristics of the process of magnetisation, including the variations of susceptibility which occur as the magnetising force is increased.

3. That the intermolecular magnetic forces are equally competent to account

for the known facts of retentiveness and coercive force and the characteristics of cyclic magnetic processes.

4. That magnetic hysteresis and the dissipation of energy which hysteresis involves are due to molecular instability resulting from intermolecular magnetic actions, and are not due to anything in the nature of frictional resistance to the rotation of the molecular magnets.

5. That this theory is wide enough to admit explanation of the differences in magnetic quality which are shown by different substances or by the same substance in different states.

6. That it accounts in a general way for the known effects of vibration, of temperature, and of stress upon magnetic quality.

7. That in particular it accounts for the known fact that there is hysteresis in the relation of magnetism to stress.

8. That it further explains why there is, in magnetic metals, hysteresis in physical quality generally with respect to stress, apart from the existence of magnetisation.

9. That, in consequence, any (not very small) cycle of stress occurring in a magnetic metal involves dissipation of energy.

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6. *Some Experiments to determine Wave Velocity in certain Dielectrics.* *By* FRED. T. TROUTON.

The general method employed was described in 'Nature,' January 1890. In Hertz's well-known experiment of 'Loops and Nodes' a sheet of a dielectric is inserted between the reflector and the resonator. The effect of this is to shift the system of loops and nodes towards the reflector. From the amount of this shift the index of refraction can be found. If the reflection from the surfaces be neglected $\mu = \frac{x_0 - x}{l}$ where x_0 is the distance to the node in air or one quarter of the wave-length, and x the distance on inserting the sheet, l being the thickness of the sheet. A more complete formula, where the multiple reflections are considered, as in Newton's rings, is

$$\tan \pi \frac{(x_0 - x)}{x_0} = \frac{2\mu \sin \pi \frac{\mu l}{x_0}}{(\mu^2 - 1) + (\mu^2 + 1) \cos \frac{\pi \mu l}{x_0}}.$$

Experiments were made with pitch, solid paraffin, and sulphur. The index, as determined from the more complete formula for pitch, was found to be about 1·7 (Hertz with his great pitch prism found about the same), but for sulphur and paraffin it came out quite too large—between 3 and 4. An explanation of this was put forward in the paper. The size of the reflector employed was so small that it introduced diffraction phenomena; that is to say, the nodes were situated further out than if an infinite plane were used as reflector (see 'Nature,' August 1889). This is caused by the increased velocity of the disturbance near a small-sized reflector. The explanation put forward maintains that this abnormal value of the velocity is effected in a greater ratio by the insertion of the dielectric sheet than the normal velocity would be. Taking the value of this velocity at distance r as $V = v \frac{\mu^2 m^2 r^2 + 1}{\mu^2 m^2 r^2}$, where v is the normal value, it was shown that the index or ratio of the velocities at distance r was greater than μ, the normal index. This would explain why pitch came out satisfactorily, while paraffin and sulphur did not. For the pitch sheet was over 6 cm. thick, while the other two were only about 3 cm.

Part of the paper contained an account of experiments on the absorptive powers of certain substances made by obtaining reflection from thin sheets. Thus glass and limestone 2 cm. thick afforded reflection. This is no doubt due to the absorption of the beam reflected from the back being so weakened by absorption that it is unable to interfere with that from the front and produce 'darkness,' as it does in the case of paraffin, &c.

Other experiments with substances in the state of powder, such as chalk, sand, &c., were made. These absorbed but slightly. Lampblack acted more strongly.

SATURDAY, SEPTEMBER 6.

The following Papers were read:—

DEPARTMENT I.—MATHEMATICS.

1. *On the Physical Character of Caustic Surfaces.* By J. LARMOR.

The diffraction produced at a caustic is peculiar in that it is not conditioned by a beam of light limited by an aperture or otherwise. The theoretical explanation why undulations, propagated by unlimited wave-fronts, cannot penetrate beyond a certain geometrical surface, was slightly indicated by Thomas Young, and fully worked out on Fresnel's principles by Sir G. B. Airy, for the special case of the rainbow.

It is worth while to formulate the general law of the thicknesses of the bright bands which, for any kind of homogeneous light, lie parallel to the principal physical caustic. As the beam of light is determined solely by the geometrical caustic, or ray-envelope, it is clear that the law must be expressed in terms of this surface. It comes out that

The bands form, along with the geometrical caustic, a system whose relative distances apart are in every case the same, and whose absolute distances at any point are proportional to the two-thirds power of the radius of curvature of the caustic surface at the point, measured in the direction of the rays.

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2. *The Buckling of Plates.* By G. H. BRYAN.

In this paper are worked out the analogues for a plane plate of the well-known conditions of stability of a straight elastic wire under axial force.

The first case considered is that of a rectangular plate, supported but not clamped round its boundary, and acted on by different uniform edge thrusts in its plane applied perpendicularly to the sides and ends. The conditions of stability are found, and the most interesting point which they lead to is the determination of the number of corrugations produced when buckling takes place. If the thrust per unit length on the sides be less than half that on the ends, the plate will buckle into a series of undulations, whose number will depend on the ratio of the length to the breadth of the plate. In the case of an infinitely long strip the corrugations will divide the strip into rectangles, which will diminish in length as the lateral thrust is diminished, will become squares when there is end thrust only, and will become closer and narrower when the lateral force changes sign and becomes a tension. This effect may be easily illustrated by wetting the middle of a sheet of thin paper, which is then stretched over two rulers. If now the rulers be pulled apart with increasing force, the wrinkles will become more numerous and finer.

The undulatory character of the buckling is also analogous to the 'collapse into rings' of a boiler flue.

The paper also contains an investigation of the stability of a circular plate clamped round the edges, and acted on by uniform normal edge thrust in its plane. This kind of buckling is well illustrated in the circular lid of a canister whose rim is in a state of tension.

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3. *On the Pulsations of a Rotating Bell.* *By* G. H. Bryan.

It is well known that if a vibrating elastic rod of circular section be rotated upon its axis, the plane of vibration remains fixed in space, instead of turning with the rod—an experiment frequently used to illustrate the corresponding property of polarised light. If, on the other hand, a tuning-fork be rotated, beats will be heard which indicate that the vibrations turn with the fork.

The object of the present paper is to show that when a vibrating ring, cylinder, bell, or other elastic shell in the form of a surface of revolution is rotating about its axis of figure, the nodes and points of maximum radial motion will not remain fixed either in space or in the body, but will turn about the axis with angular velocity less than that of the body. The author first proves this mathematically for a ring or cylinder. As in the investigations of Hoppe and Lord Rayleigh, this is supposed inextensible, and in order to show more fully the difference between the actual effects of rotation and the purely statical effects of centrifugal force, the author supposes the ring to be acted on by an attraction to the centre varying directly as the distance, which may be so chosen as to counteract the latter force. Taking the type of vibration, which has $2n$ nodes, it is shown that these nodes rotate about the axis with angular velocity—

$$\frac{n^2-1}{n^2+1}\omega,$$

where ω is the angular velocity of the ring. Instead, therefore, of hearing $2n$ beats per revolution, as we should if the nodes remained fixed relatively to the ring, we actually only hear

$$2n\frac{n^2-1}{n^2+1}$$

beats per revolution. Putting $n=2, 3$, &c., we find the corresponding numbers to be 2·400, 4·800, 7·059, 9·231, 11·351, &c., approximately.

The author finds that the results of experiment agree pretty closely with theory. A champagne-glass was clipped on a microscopist's turn-table, which was set in motion by a string twisted once round its axle. One end of this string was held in the hand and the other passed over a smooth peg, and was attached to a weight. The glass having been struck, the number of beats was counted while the weight was drawn up from the floor to the peg, the number of revolutions being counted separately. Two glasses were used, and rotated with various angular velocities; the results for the fundamental tone being respectively 2·6 beats per revolution (11 observations), and 2·2 beats per revolution (26 observations). Considering the vast difference between the champagne-glasses used in these rough experiments and the ring or cylinder of Hoppe, the agreement of observation with theory is remarkable; and more especially so as the mean of the observed results is exactly the number found by theory.

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4. *On the History of Pfaff's Problem.* *By* A. R. Forsyth, *F.R.S.*

The paper was an abstract of Chapter III. of the author's 'Theory of Differential Equations,' Part I., Exact Equations and Pfaff's Problem, subsequently published.

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5. *On some Geometrical Theorems relating to the Powers of Circles and Spheres.* *By* Professor William Woolsey Johnson.

The determinant of the powers of three circles relatively to three other circles was shown to be sixteen times the product of the areas of the triangles, whose vertices are the centres of the circles of each group into the relative power of the circles orthogonal to the groups. It vanishes only when these circles cut at right angles.

In like manner the corresponding determinant for two groups of four spheres each is 288 times the product of the volumes of the tetrahedrons, whose vertices are the centres into the power of the spheres orthogonal to the two groups. In particular the determinant of squared distances vanishes for two groups of four points each, taken respectively on two spheres which cut at right angles; and also for two groups of three points each, if the circle passing through one group cuts at right angles any sphere passing through the other groups.

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6. *Possibility of Irreversible Molecular Motions.* *By* E. P. Culverwell, *M.A.*

In a paper in 'Phil. Mag.' July 1890, I have shown by examples, as well as by general reasoning, that there is nothing in the *general* equations of Dynamics in virtue of which the configuration of a system tends to a permanent average state, *independent of the initial conditions—i.e.*, to such a configuration as accords with the second law of Thermodynamics. To reconcile actual phenomena with the hypothesis of reversible motion, it would be necessary to show that the initial configurations are always of a very special type; for there are as many sets of initial conditions in which the subsequent motion would violate the second law as there are sets in which it would fulfil that law.

It is now pointed out that the reversibility of ultimate motions is an entirely unproved hypothesis. If the laws of motion are fulfilled by bodies composed of particles whose molecular motions are irreversible, the above difficulty is avoided, because it is evident that irreversible systems may tend to a final condition quite independent of the initial conditions.

Treating bodies as composed of molecules (which may, however, themselves be composed of an indefinite number of subsidiary particles), it is shown that there are myriads of systems of which the motions of the molecules are *irreversible,* and which yet obey the Newtonian laws of motion when taken *en másse.* Of these systems one of the simplest examples is composed of groups of six molecules or particles, P_1, P_2, P_3, P_4, P_5, P_6; the force on the particle P_1, due to P_2, P_3, P_4, P_5, P_6, as measured by its acceleration, may consist of an ordinary function of the masses and distances of the particles, together with a part involving the velocities in the following way:—the x-acceleration of P_1 varies as the x-velocity of P_2 multiplied by the volume (taken with proper sign) of the tetrahedron formed by P_3, P_4, P_5, and P_6, and so on for the others, the force, of course, changing sign when one particle, say P_3, passes through the plane of the other three, say P_4, P_5, and P_6. The motion of such a system obeys *accurately* the Newtonian laws of motion—*i.e.*:

$$\Sigma(m\ddot{x}-\mathrm{X})=0,\ \Sigma\left\{y(m\ddot{x}-\mathrm{X})-x(m\ddot{y}-\mathrm{Y})\right\}=0,$$

together with the conservation of energy—*i.e.*:

$$\Sigma(\tfrac{1}{2}m\dot{x}^2+\mathrm{V})=\Sigma(\mathrm{X}dx+\mathrm{Y}dy+\mathrm{Z}d_2).$$

Another class of irreversible motions is given in which, though the Newtonian laws of motion are *accurately* fulfilled, the body loses energy or gains energy as the case may be. It is also shown that, on the ordinary potential theory, the centre of mass of a body composed of particles could not *accurately* fulfil the Newtonian laws of motion when energy was communicated to it—*i.e.*, when it rose in temperature.

It is then pointed out that it is not necessary that the laws of motion should be *accurately* fulfilled, but only that the divergence should be periodic, the period being so short that no observations could detect it; and this opens up another wide range of possible irreversible hypotheses consistent with observed facts.

It is then contended that irreversible motions, in which a portion of the force with which one particle or portion of matter acts on another, or on the ether, depends on the *velocities* of the particles relative either to each other or to the ethereal medium in which they exist, must be accepted as a scientific hypothesis.

7. *On some Arithmetical Functions connected with the Elliptic Functions of $\frac{1}{3}K$.* *By* Dr. J. W. L. GLAISHER, *F.R.S.*

8. *On Systems of Simultaneous Linear Differential Equations.* *By* A. R. FORSYTH, *F.R.S.*

9. *Chess Problem.*[1] *By* Lieut.-Col. ALLAN CUNNINGHAM, *R.E.*

'To find the number of different positions after two moves on each side at the game of chess.'

This is—in a mathematical sense—a fairly simple problem in combinations; but the rules of chess introduce into it such a number of variations requiring separate estimation, as to make the complete solution a pretty laborious task. Without great care in the detail there is much risk of omission, also of counting the same position twice, and of counting positions which cannot be formed in actual play.

On account of the great historic interest of the game of chess, it is thought worth while to publish the results. The following is an abstract:—

I. Pawns only moving	16,556
II. Captures by pawns; at least one piece moved	347
III. No captures by pawns; both sides move at least one piece	19,441
IV. No captures by pawns; one side moves pawns only, the other side moves at least one piece	35,438
Grand total	71,782

10. *On a Remarkable Circle through two Points of a Conic.* *By* Professor GENESE, *M.A.*

A, B are two fixed points of a conic, C the pole of AB, P a variable point or the curve. Through C an antiparallel is drawn to AB with respect to the angle APB, meeting its arms in Q, Q′; in other words, QCQ′ is drawn so that the points A, B, Q′, Q lie on a circle. *This circle is invariable.*

AQ′, BQ meet on the conic, at P′, say; then PP′ passes through a fixed point T (the pole of AB with respect to the circle).

Thus, using C, the circle can, by means of the ruler, be transformed into the conic, or, using T, the conic can be retransformed into the circle.

It will be noticed that the point T has the property that for any chord PP′ through it the sum of the angles APB, AP′B with a proper convention is constant.

11. *Ferrel's Theory of the Winds.* *By* CHARLES CHAMBERS, *F.R.S.*

The object of this paper is to point out a defect in Dr. Ferrel's analytical investigation of the motions of the atmosphere, to supply that defect, and to substitute legitimate interpretation and geometrical illustrations of the analytical results arrived at for a misleading and irrelevant exposition given in several of the revisions of Dr. Ferrel's research that have been published from time to time during the last thirty years.

DEPARTMENT II.—GENERAL PHYSICS AND ELECTROLYSIS.

1. *On a Method of determining in Absolute Measure the Magnetic Susceptibility of Diamagnetic and Feebly Magnetic Solids.* *By* Sir WILLIAM THOMSON, *D.C.L., LL.D., F.R.S.*

The communication was suggested from two directions in which the subject had been treated—(1) Professor Rücker's investigations of the magnetic suscepti-

[1] This problem has been published *in extenso* in the *Royal Engineers' Journal* for 1889.

bility of basaltic rocks, to which he was led in the interpretation of the results of the great magnetic surveys made by himself in conjunction with Dr. Thorpe, by which remarkable disturbances due to magnetisation of the rocks and mountains were found; (2) Quincke's determinations of the magnetic susceptibility of liquids. The method proposed by the author consisted in measuring the mechanical force experienced by a properly shaped portion of the substance investigated, placed with different parts of it in portions of magnetic field between which there was a large difference of the magnetic force. A cylindrical or rectangular or prismatic shape, terminated by planes perpendicular to its length, was the form chosen; the component magnetic force in the direction of its length was equal to $\frac{1}{2}\mu(R^2-R'^2)A$; where μ denoted the magnetic susceptibility, R, R′ the magnetic force in the portions of the field occupied by its two ends, and A the area of its cross-section. For bodies of very feeble susceptibility the best arrangement of field was that originally adopted by Faraday, and pushed so far recently by Professor Ewing, in the way of giving exceedingly intense fields. One end of the prism, or plate, or wire was in the air between flat ends and conical magnetic portions; the other might be in a place practically out of the field, or, if the portion of the substance given were exceedingly small, it might be in the field, but in a place of much less force than in the centre of the field. The measurement of the magnetic force of the field was easily made by known methods: best by measuring the force experienced by a short element of wire carrying a measured current. This portion of wire should be placed in the positions occupied by the two ends of the plate or wire of the substance, first in one position and then in the other. But when the second position was in a place of sensibly known force, the single measurement with the element of the wire in the first position sufficed.

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2. *On the Tension of Water Surfaces, Clean and Contaminated, investigated by the Method of Ripples.* By Lord RAYLEIGH, *Sec.R.S.*

The ripples were rendered visible by a combination of Foucault's optical arrangement with intermittent illumination. Two frequencies were used, about 43 and 128 per second. The principal results may be thus summarised. The tension of a water surface, reckoned in C.G.S. measure, is, in the various cases:

Clean	74·0
Greasy to the point where the camphor motions nearly cease	53·0
Saturated with olive oil	41·0
Saturated with oleate of soda	25·0

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3. *On the Adiabatic Curves for Ether, Gas and Liquid, at High Temperatures.* By Professor W. RAMSAY, *F.R.S.*

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4. *Report of the Committee on Electrolysis.*—See Reports, p. 138.

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5. *Report on the State of our Knowledge of Electrolysis and Electro-Chemistry.* By W. N. SHAW.—See Reports, p. 185.

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6. *On the Action of Semi-permeable Membranes in Electrolysis.* By Professor W. OSTWALD.

The author gave an account of experiments upon the passage of an electric current through solutions in series separated by semi-permeable membranes, and pointed out the importance of such phenomena to physiology. He explained that a semi-permeable membrane would allow ions of one kind to pass through, but arrest ions of another kind, and thus act as though it were a metallic electrode. The deposit of copper upon a semi-permeable membrane forming the cathode boundary between copper sulphate solution and a solution of ferrocyanide of potassium was demonstrated experimentally to the meeting. The paper appears in the 'Zeitschrift für Physikalische Chemie,' vol. vi. p. 71, 1890.

MONDAY, SEPTEMBER 8.

The following Reports and Papers were read:—

1. *Report of the Committee on the Ben Nevis Observatory.* See Reports, p. 174.

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2. *Report of the Committee on Tidal Observations in Canada.* See Reports, p. 183.

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3. *Report of the Committee for Comparing and Reducing Magnetic Observations.*—See Reports, p. 172.

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4. *Report of the Committee for Determining the Seasonal Variation in the Temperatures of Lakes, Rivers, and Estuaries.*—See Reports, p. 92.

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5. *Report of the Committee on Solar Radiation.*—See Reports, p. 144.

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6. *Report of the Committee on the Volcanic and Seismological Phenomena of Japan.*—See Reports, p. 160.

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7. *On a Meteorological Observatory recently established on Mont Blanc.* *By* A. LAWRENCE ROTCH, *S.B., F.R.Met.Soc. of Boston, U.S.A.*

It is generally conceded that the future progress of meteorology depends chiefly upon the study of the upper regions of the atmosphere. Thus the vital, and at the present time, disputed question as to the vertical decrease of temperature in cyclones and anti-cyclones, upon which rest our theories of the general movements of the atmosphere, and hence our deductions expressed in weather forecasts, can only be settled by simultaneous observations at high and low altitudes. Disregarding balloons as unavailable for this purpose, we must turn to the mountain observatories, for whose establishment and maintenance large sums of money have been expended by various nations.

Until recently the highest meteorological station in the world was in the United States on Pike's Peak, at an elevation of 14,134 feet above the sea, while among the ten or more European stations, the loftiest has been that in the Austrian Alps on the Sonnenblick, at an altitude of 10,170 feet. The French, however, who have contributed more towards mountain meteorology than any other nation by their fine observatories on the Pic du Midi, the Puy de Dôme, and the Mont Ventoux, may now claim what is probably the highest meteorological station in the world in the one which has just been established by M. J. Vallot on Mont Blanc, at an altitude of about 14,320 feet above sea-level.

The summit of Mont Blanc, rising to a height of 15,780 feet, and dominating the neighbouring mountains, offers an admirable site for a meteorological station, but the shifting snow renders the erection there of a permanent building impracticable. The site chosen by M. Vallot was at the Rocher des Bosses, about 1,460 feet below the summit, and here he has re-erected a wooden cabin, constructed at Chamonix, and carried up in pieces on the backs of guides and porters. The cabin is intended to serve both as a refuge for tourists and as a meteorological and physical observatory. The latter is completely equipped with the registering meteorological instruments of Richard Brothers, which operate during fifteen days without attention, and it is hoped to maintain them in action during four consecutive months. Their installation will not be completed this year, and several intermediate stations are proposed, including a similar cabin to be erected by M. Janssen, the French physicist, at the Grands Mulets, at an elevation of 10,000 feet. A base station at Chamonix (3,450 feet) is already in operation. Further details from the author's personal inspection will be given in the 'American Meteorological Journal.'

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8. *The Climate of Scarborough compared with that of some other Seaside Health Resorts.*[1] *By* JOHN HOPKINSON, *F.L.S., F.G.S., F.R.Met.Soc.*

After giving reasons for inferring that meteorological observations taken continuously during the decade 1880–89 may advantageously be utilised to deduce the most important elements of the climate of any place in the British Isles, the author showed that observations taken at Scarborough during this period fulfilled the necessary requirements as to accuracy and continuity, and also as to uniformity with those taken at other places with which he compared the principal results.

A table showing the monthly and annual means of temperature (mean, mean minimum, mean maximum, and mean daily range), relative humidity, cloud, and rainfall, and the extremes of temperature at Scarborough, for this decade, was given, and the general results of comparison with the chief elements of the climate of four other seaside health-resorts, situated in succession at nearly equal distances round our coast, were summarised thus:—

1880–89	Temperature						Humidity at 9 a.m.	Cloud at 9 a.m.	Rain-fall
	Means				Extremes				
	Mean	Min.	Max.	Range	Min.	Max.			
	°	°	°	°	°	°	%	0–10	Ins.
Scarborough	47·5	42·6	52·5	9·9	10·5	83·8	83	6·6	28·26
Lowestoft	48·2	42·4	53·9	11·5	9·2	87·0	83	6·8	24·15
Worthing	49·5	43·7	55·3	11·6	13·5	83·3	83	5·9	26·55
Babbacombe	49·9	44·0	55·9	11·9	15·6	85·6	82	7·0	33·58
Llandudno	49·2	44·1	54·3	10·2	14·5	84·0	79	6·9	29·13
Mean	48·9	43·4	54·4	11·0	12·7	84·8	82	6·6	28·33

Scarborough is thus about a degree and a half colder than the mean of the five places, has about a degree less mean daily range of temperature, is one per cent. more humid, and has the mean amount of cloud and nearly the mean rainfall.

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9. *The Inland compared with the Maritime Climate of England and Wales. By* JOHN HOPKINSON, *F.L.S., F.G.S., F.R.Met.Soc.*

The author first endeavoured to show that the chief difficulties in making a satisfactory comparison between our inland and our maritime climate would be

[1] Printed *in extenso* in the *Scarborough Mercury* of September 19, 1890.

removed if a sufficient number of meteorological stations could be found which represent approximately the mean height and the range of the height of the land in the interior and near the coast, and if the mean position of both the inland and the maritime places were almost identical and not far distant from the centre of England. From the 'Meteorological Record' of the Royal Meteorological Society, compiled by Mr. W. Marriott, he selected, as approximately fulfilling these conditions, Buxton, Woburn (Aspley Guise), Croydon (Addiscombe), Cheltenham, and Churchstoke, to represent the interior of the country, and Scarborough, Lowestoft, Worthing, Babbacombe, and Llandudno, to represent the sea coast. The mean height above the sea of the meteorological stations at the five inland places is 469 feet, and the mean height of those at the five maritime places is 124 feet, the range in the former being from 184 to 987 feet, and in the latter from 21 to 293 feet. The mean latitude of the five inland places is 52° 12′ N.; the mean longitude, 1° 32′ W. The mean latitude of the five maritime places is 52° 22′ N.; the mean longitude, 1° 16′ W. The mean position indicated is, in each case, near the centre of England (a little south of Birmingham).

The values for the decade 1880–89 for the chief elements of the climate of the five places situated on the coast are given in the author's paper on the climate of Scarborough, and in the following table those for the five places situated in the interior, with the means, and, for easy comparison, the means for the seaside places, and for the whole :—

1880–89	Temperature						Humidity at 9 a.m.	Cloud at 9 a.m.	Rain-fall
	Means				Extremes				
	Mean	Min.	Max.	Range	Min.	Max.			
	°	°	°	°	°	°	%	0–10	Ins.
Buxton . .	44·6	37·6	51·6	14·0	−4·0	82·1	85	7·3	48·09
Woburn . .	47·6	40·4	54·8	14·6	−1·0	86·1	83	7·5	32·06
Croydon . .	48·8	41·9	55·8	13·9	11·6	92·4	80	7·4	25·56
Cheltenham .	47·9	40·4	55·4	15·0	−3·3	87·8	83	7·0	28·86
Churchstoke .	46·7	40·4	54·8	14·4	6·9	90·7	83	6·9	24·46
Mean { Inland .	47·1	39·9	54·3	14·4	2·0	87·8	83	7·2	31·81
Mean { Maritime	48·9	43·4	54·4	11·0	12·7	84·8	82	6·6	28·33
Mean of all .	48·0	41·65	54·35	12·7	7·35	86·3	82·5	6·9	30·07

The chief conclusion to be drawn from this table appears to be that in every respect, so far as regards our comfort, and most probably also our health, our maritime climate is on the whole superior to our inland climate, being warmer, owing (it is most important to be observed) to the nights not being so cold while the days are no hotter, the extremes of temperature being much less, the air rather less humid, the sky less cloudy, and the rainfall less.

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10. *A Comparison of the Climate of Halifax, Wakefield, Bradford, Leeds, and Hull.* *By* JOHN HOPKINSON, *F.L.S., F.G.S., F.R.Met.Soc.*

Meteorological observations having been taken at these five manufacturing towns in the South of Yorkshire during the decade 1880–89 with sufficient uniformity and continuity for a tolerably satisfactory comparison to be made,[1] the author gave the principal results for this purpose in the following table :—

[1] The position of the instruments at Bradford and Leeds is not satisfactory.

1880–89	Temperature						Humidity at 9 a.m.	Cloud at 9 a.m.	Rain-fall
	Means				Extremes				
	Mean	Min.	Max.	Range	Min.	Max.			
	°	°	°	°	°	°	%	0–10	Ins.
Halifax . .	46·5	39·6	53·4	13·8	10·0	89·0	83	7·0	36·55
Wakefield . .	47·7	41·0	54·4	13·4	11·5	86·8	84	7·3	28·01
Bradford . .	48·0	42·4	53·7	11·3	12·0	84·4	79	7·2	30·15
Leeds. . .	48·8	42·6	55·1	12·5	12·0	87·0	81	6·7	25·53
Hull . . .	47·1	39·9	54·3	14·4	6·0	85·0	81	6·3	27·07
Mean . .	47·6	41·1	54·2	13·1	10·3	86·4	81½	6·9	29·46

In order to render more perspicuous the relation which the above values bear to the mean and to each other, the deviations per cent. from the mean were deduced (all the deviations in temperature being computed in percentages of the mean temperature), with the following result :—

1880–89	Temperature						Humidity at 9 a.m.	Cloud at 9 a.m.	Rain-fall
	Means				Extremes				
	Mean	Min.	Max.	Range	Min.	Max.			
	%	%	%	%	%	%	%	%	%
Halifax . .	−2	−3	−2	+1	−1	+5	+2	+2	+24
Wakefield . .	=	=	+1	+1	+2	+1	+3	+6	− 5
Bradford . .	+1	**+3**	−1	−4	+4	−4	−3	+4	+ 2
Leeds. . .	+2	+3	+2	−1	+4	+1	−1	−3	−13
Hull . . .	−1	−3	=	+3	−9	−3	−1	−9	− 8

11. *Photographs of the Invisible, in Solar Spectroscopy.* *By* C. Piazzi Smyth, *LL.D.*

The photographs submitted on this occasion are two, each of them murally mounted and measuring 40 inches long by 20 high. They represent in reality only very small portions of the faint ultra-violet of the Solar Spectrum, but on a whole scale of 57 feet long from red to violet, and are located quite outside the spectral limits of visibility to the human eye, with the grating spectroscope concerned, whether under summer or winter sun.

Yet the previous empty fields of ultra-violet view became filled with wondrous detail as soon as they were entrusted for record to actinism and the photographic film. This, too, in dull winter weather, with a lamentably low sun, on December 12, 1889, or when the eye could see only less than nothing.

Some degree of power in photography to record further into the spectrum than the human eye has long been well known; but in this instance there had been supposed proof obtained of a positive incapacity of the grating's metal substance to reflect ultra-violet, or even violet, light. Yet here this accusation has been shown to be false the moment photography was applied, and powerful pictures have been procured thereby, as witness these enlargements by Mr. S. H. Fry, at Kingston-on-Thames, from the author's original negatives on glass.

The definition is not indeed yet what the author desires, but he expects soon to make it so, by aid of a contribution lately received from the Government Grant Committee of the Royal Society; so that then, having a sufficient supply of electricity already on the premises, he may be able to photograph a more crucially telling comparison between certain earthly elements and the Solar Spectrum lines than has yet been accomplished; if, indeed, the present meeting will extend to him, among the annual votes for the promotion of science, a sufficient one for carrying on an end-on-gas-vacuum-tube method of photographing, which is alone suitable to high spectroscopy.

12. *On Meteorological Photography.* *By* John Hopkinson, *F.L.S., F.G.S., F.R.Met.Soc.*

The author called attention to the increasing importance attached to photography as a means of illustrating scientific subjects and aiding in scientific research. In no branch of science, he thought, could photography be of greater value than in meteorology, owing to the transient nature of meteorological phenomena.

The appointment of a Committee of the British Association on Meteorological Phenomena, by which committee instructions to photographers would be issued with the view of instituting a systematic method of working, &c., would, he felt sure, greatly extend the interest taken in the subject and increase the scientific value of the results. The chief object of such a committee would be to investigate and report upon the means by which photography can most advantageously be applied to the elucidation of meteorological phenomena, such as the forms of clouds, lightning flashes, and the effects of storms. The committee would also undertake the collection of photographs of such phenomena and keep a register of them, reporting additions annually, and would compile a bibliography of the subject.

In the study of the various forms of clouds, the author believed that a satisfactory classification could best be made by the comparison of numerous photographs; the relation between cloud forms and atmospheric pressure and temperature would be an interesting field for research; and an attempt might be made to ascertain the best means of overcoming the difficulty of photographing light clouds on a blue sky, due to blue rays being almost as powerfully actinic as white. In the investigation of lightning by photography special attention would be given to the phenomenon of the appearance on the plate of so-called dark flashes, with the object of arriving at a conclusive explanation of the effect, and an endeavour might possibly be made to determine whether lightning really forms a streak or a point in excessively rapid motion. The collection and exhibition of photographs showing the destructive effects of storms—whether the destruction or damage were wrought by rain, by wind, or by lightning—might not be considered of such scientific importance as the investigation of clouds and lightning, but it would add much to the general interest of the inquiry.[1]

13. *On the Spectra of the Elements and the Constitution of the Sun.* *By* Professor H. A. Rowland.

14. *On Regional Magnetic Disturbances in the United Kingdom.* *By* Professors A. W. Rücker, *F.R.S., and* T. E. Thorpe, *F.R.S.*

15. *Sur les perturbations magnétiques en France.* *By* Professor E. Mascart.

16. *Exhibition of Photographs of Clouds.* *By* Friese Greene.

[1] The Committee here suggested was appointed.

TUESDAY, SEPTEMBER 9.

The following Papers and Reports were read:—

1. *Optique minéralogique.—Achromatisme des Franges.*
By Professor E. MASCART.

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2. *Instantaneous Photographs of Water Jets.*
By Lord RAYLEIGH, *Sec.R.S.*

These photographs were taken by the light of the electric spark. A battery of Leyden jars was charged by a Wimshurst machine, and discharged itself between brass balls, held almost half an inch apart, in the optical lantern. By means of a large condenser a good proportion of the light was concentrated upon the lens of the camera. The jet of water, regularised by a tuning-fork, fell in front of the condenser, and was focussed upon the photographic plate.

In the absence of anything to diffuse the light, the pictures are simple shadows, such as have been obtained without any optical appliances by Mr. Bell and Mr. Boys. The only detail is due to the lens-like action of the jets and the drops into which it is resolved. This arrangement is quite sufficient to illustrate the behaviour of electrified jets. But the interposition of a plate of ground glass close to the condenser effects a great improvement in the pictures by bringing out half tones, and the results printed on aristotype paper are now very good. The only difficulty is that due to the loss of light. In some of the experiments it was found advantageous to diminish the diffusion by slightly oiling the ground glass.

The degree of instantaneity required depends upon circumstances. In some cases the outlines would have lost their sharpness had the exposure exceeded $\frac{1}{10000}$ second. It is probable that the actual duration of the principal illumination was decidedly less than this.

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3. *Report of the Committee on Electrical Standards, including the four following Papers.*—See Reports, p. 95.

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4. *On Variations in some Standard Resistance Coils.*
By R. T. GLAZEBROOK, *F.R.S.*—See Reports, p. 98.

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5. *On some Standard Air Condensers.* *By* R. T. GLAZEBROOK, *F.R.S.*, and Dr. A. MUIRHEAD.—See Reports, p. 102.

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6. *On the Specific Resistance of Copper.*
By T. C. FITZPATRICK.—See Reports, p. 120.

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7. *A Comparison of a Platinum Thermometer with some Mercury Thermometers.* *By* E. H. GRIFFITHS.—See Reports, p. 130.

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8. *On the Character of Steel used for Permanent Magnets.*
By W. H. PREECE, *F.R.S.*

The quality of English magnet steel having apparently deteriorated, and being much below that of France, led the author to make an exhaustive inquiry into the comparative merits of each kind. Samples were obtained from all the leading makers of both countries, magnets were made, and a careful magneto-metric series of measurements taken for some months. The French steel showed itself to be far superior to the English. The details of the comparison are given in the paper,[1] but the reasons for this marked superiority remain for further investigation.

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9. *The Effect of Oxidation on the Magnetic Properties of Manganese Steel.* *By* L. T. O'Shea, *B.Sc.*

When manganese steel drillings are oxidised they become magnetic, the development of magnetic properties being due to removal of manganese by oxidation and to the magnetic properties of the oxide of iron (probably magnetic oxide) formed.

When the oxidised product is reduced in hydrogen, the iron oxide is converted into metallic iron and the manganese remains as manganous oxide (MnO). The reduced steel is now powerfully magnetic in virtue of the magnetic properties of unalloyed metallic iron.

During the process of oxidation the proportion of manganese to iron oxidised in a given time is only very slightly in excess of the proportion of manganese to iron in the original steel. The excess of manganese oxidised is, in all probability, due partly to the greater susceptibility of manganese to oxidation, and partly to the heterogeneous structure of the steel.

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10. *On Testing Iron.*[2] *By* J. Swinburne and W. F. Bourne.

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11. *The Compensation of Alternating-Current Voltmeters.*[2] *By* J. Swinburne.

The communication relates to an arrangement for compensating alternating voltmeters for changes of frequency.

It is much more easy to make a current indicator for alternating than direct currents, for troubles from hysteresis do not come in, and the slight tremble makes the moving part hang freely. If it is attempted, however, to use such an instrument as a voltmeter, the self-induction makes the reading far too low, and the error varies with the frequency.

To get over this trouble, a voltmeter may have a non-inductive, or nearly non-inductive, resistance put in series with its active coil. A coil with an adjustable iron core is then put in shunt to the active coil, this shunt coil having a very much larger time-constant. The instrument is calibrated with a direct current. An alternating current is then put on, and the core of the shunt coil regulated till the readings agree with those of the direct current.

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12. *Note on a Kinetic Stability of Equilibrium with Electro-magnetic Forces.* *By* Professor G. F. Fitzgerald, *F.R.S.*

If a perfect conductor move near a magnet there are currents induced in it which tend to stop the motion. If the conductor be perfect, the kinetic energy of motion will ultimately, if small enough, be all changed into electrokinetic energy and the conductor will begin to move in the opposite direction, and when in its former position its electrokinetic energy will have been reconverted into kinetic energy. For instance, if a perfect conducting shell were placed near three magnetic poles it would be in a state of kinetic equilibrium, if the energy given to it by a small disturbance were not great enough to drive it to infinity or into contact with the magnet. It is to be remarked that I have assumed the perfect conductor to have been brought within a finite distance of the magnet pole without having

[1] Published in the *Electrician*, September 19, 1890.
[2] *Electrician*, October 1890.

had currents induced in it—*i.e.*, I have assumed that the body can be brought up as an imperfect conductor and then changed into a perfect conductor *in situ*. As the effect of a magnetic pole is to induce in a perfect conducting plane sheet currents which can be magnetically represented by a pole at the reflection of the first pole in the sheet, it follows that with a perfect conducting sheet there would be no action, such as in Arago's experiment prevents motion of the sheet parallel to itself. There would, no doubt, be a gradual radiation of the energy due to the varying magnetic fields. This would have a damping effect on the vibrations, much the same as would result from resistance in the conductor. If there were a constant force like gravity acting, the equilibrium might exist only for the radiation of energy. There is no very great difficulty in calculating the conditions for vibrational and logarithmic motions respectively.

The system is interesting as an illustration on a large scale of how meteoric swarms have their energy gradually frittered away into electromagnetic radiations.

13. *On Electrical Oscillations in Air.*[1] *By* J. Trowbridge.

14. *On the Electrostatic Forces between Conductors and other matters in connection with Electric Radiation.*[2] *By* Professor Oliver J. Lodge, *F.R.S.*

The author gives an account of an investigation into the forces between electric resonators as examined experimentally by Boys, and therefrom branches out into several allied subjects connected with the mechanical forces of electric pulses and waves.

WEDNESDAY, SEPTEMBER 10.

The following Papers were read:—

1. *On Atom-grouping in Crystals (with exhibition of a Model).* *By* W. Barlow.

After referring to some comments made by Sir William Thomson and Professor Sohncke on a paper on the same subject read by the author at the Aberdeen Meeting of the Association in 1885,[3] the author stated one of the objects of the present paper to be to call attention to some interesting properties of the simpler kinds of symmetrical grouping of points, and to an easy method of studying them by means of the model exhibited.

He then described the model as consisting of parallel equi-distant planes of homogeneously distributed points (réseaux) represented by beads, and furnished with an appliance for simultaneously moving the planes nearer together or further apart, while still keeping them equidistant.

He pointed out that if a series of similar triangularly arranged plane systems are so placed in the model, and the distances between the planes so chosen that the assemblage of points has the grouping of the cubic system, of which we have an example in the arrangement of the centres in a triangular stack of cannon-balls,[4]

[1] The paper is printed in full in the *Proceedings of the American Academy of Arts and Sciences*, vol. xxv. (N.S. xvii.)

[2] The paper appears in the *Philosophical Magazine* for September 1890.

[3] See 'On the Constitution of Matter,' by Sir William Thomson, *Proceedings Royal Society of Edinburgh*, 1889, pp. 712, 715, 716, and 'Erweiterung der Theorie der Krystallstruktur,' von Dr. Leonhard Sohncke, *Zeitschrift für Krystallographie, &c.*, xiv. 5, pp. 429, 430, 433, 443.

[4] See paper read by the author in 1885, published in the *Chemical News* of January 1 and 8, 1886.

then two other values for the distances apart of the planes will also give an arrangement of the points according to the cubic system, and that these values are respectively one half and one quarter of the values first employed.

He then pointed out the effects of interlacing the systems thus obtained in reproducing similar systems differing only in scale.

He then passed to the principal topic of his paper—some additional evidence in favour of the theory which he had previously put forward, that it is the different kinds of atoms of the elements rather than the molecules or units of chemical compounds which are symmetrically arranged in crystals.

Symmetrical systems of atom-arrangement were shown in the model as probably those of Iceland spar and Tetrahedrite, the numerical proportions of the beads of different colours, and the symmetry of grouping being respectively, in both cases, in harmony with the atom-composition and the crystal forms of these substances.

With regard to the former, he pointed out that the theory given by Huyghens, that the rhombohedric form of Iceland spar is derived by shrinkage of the tetrahedric form of grouping along a perpendicular to one of the faces of the pile, and the theory of Sir William Thomson that it is derived from shrinkage of a cubic grouping, have their parallel in the case of the symmetrical arrangement suggested, the grouping exhibited being derived by shrinkage of a cubic grouping. This cubic grouping was then exhibited by shifting the planes of the model further apart.

The author remarked that the view that the symmetrical grouping in Iceland spar is the result of the shrinkage of a cubic arrangement derives great support from Baumhauer's beautiful discovery that crystals of this substance can be twinned artificially by means of a knife. For corresponding to each [1] pair of alternative positions for the atoms revealed by the phenomenon there must evidently be an intermediate position similarly related to both, and, for the arrangement of the atoms in the intermediate position to be similarly symmetrical with respect to the two extreme positions *in all the three cases,* it must be derived from the cubic form.

He then suggested the probability that all crystals which do not belong to the cubic system are produced by the shrinkage of assemblages originally belonging to this system.

With regard to the atom-grouping exhibited, as probably that of Tetrahedrite, the author pointed out how completely the arrangement was in harmony with the form of the crystal—regular twin tetrahedra. He explained the method of building up the group, and pointed out its opposite polarity along perpendiculars to the faces, which corresponds with the hemihedral form which the crystal displays. And he also remarked on the fact that the disposition of the layers of different atoms resembled that of the arrangement of the elements in a thermo-electric pile, and would account for the pyro-electric properties of the substance if the atoms of different kinds exercise the same electric functions individually which they exercise when present in large masses not chemically combined, and therefore unintermixed with other atoms.

He noted that the absence of one of the two atoms of antimony would deprive the assemblage of its opposite polarity.

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2. *On an Episode in the life of J. (Hertz's Solution of Maxwell's Equations).* *By* Professor G. F. Fitzgerald, *F.R.S.*

If in Maxwell's equation of the electromagnetic field it is assumed that $J=\frac{dF}{dx}+\frac{dG}{dy}+\frac{dH}{dz}=\frac{d\Psi}{dt}$, and that instead of $\Delta^2\Psi=0$ we take $\frac{dP}{dx}+\frac{dQ}{dy}+\frac{dR}{dz}=0$, which is the real condition for no electrification at a point in a non-conductor, we get $\Delta^2\Psi=\frac{d^2\Psi}{dt^2}$. If we take F, G, H, the proper form to satisfy Maxwell's equations for

[1] There are three directions in which the knife can be held.

them, namely, $\Delta^2 F = \frac{d^2F}{dt^2}$ &c., we must assume them connected with a current intensity at each point u, v, w, by equations of the form

$$F = \iiint \frac{u_o \cos (t-r)}{r} dxdydz,$$

when $u = u_o \cos t$ is assumed as the particular case of an harmonic solution. From this we can see that

$$\Psi = \int \frac{e_o \cos (t-r)}{r}. dxdydz,$$

where $e = e_o \cos t$ is the varying electrical charge at any point, will satisfy the conditions

$$\Delta^2\Psi = \frac{d^2\Psi}{dt^2} \text{ and } -\frac{d\Psi}{dt} = J = \frac{dF}{dx} + \frac{dG}{dy} + \frac{dH}{dz}.$$

We have thus the means of calculating at any point the electric force

$$-P = \frac{dF}{dt} + \frac{d\Psi}{dx}$$

and the magnetic force $a = \frac{dG}{dz} - \frac{dH}{dy}$ if we know the distribution of electricity and electric currents in a neighbouring conductor. It is sometimes more convenient for calculation to apply this method than that of assuming a knowledge of the distribution of electric and magnetic force in the neighbourhood of the conductor. For example, in the case of a small Hertzian vibrator we get at once that if we calculate a quantity $\Pi = \frac{le_o \cos (t-r)}{r}$, then the function $\Psi = \frac{d\Pi}{dz}$ being here due to two equal and opposite charges at a distance e apart, while all the current being w, we get $H = \frac{d\Pi}{dt}$, so that Hertz's $\frac{d\Pi}{dt}$ is Maxwell's vector potential, for Hertz's equations for the electric and magnetic forces are those derived from Maxwell's in the way above described.

If we apply this method to calculate the forces due to an harmonic distribution of electrification and current on a line we require to evaluate integrals of the form

$$U = \int \frac{\sin x \ \sin r}{r}. dx$$

where

$$r^2 = x^2 + p^2.$$

If we suppose

$$\frac{\sin r}{r} = A_o + A_1, \cos x + A_2 \cos 2x + \ldots$$

we can evaluate A_n, and observing that the function satisfies the differential equation

$$\frac{d^2U}{dp^2} + \frac{1}{p}. \frac{dU}{dp} + \frac{d^2U}{dz^2} = U,$$

so that

$$\frac{d^2A_n}{dp^2} + \frac{1}{p}. \frac{dA_n}{dp} - (1+n^2)A_n = 0,$$

the solution of which is the Bessel function

$$A_n = J_o (ix\sqrt{1+n^2}).$$

If we wish to apply Hertz's method we get the same equations, but we must first see how to build up a large body with given currents and electrifications out of a number of small Hertzian oscillators. In the case of a long linear oscillator, it is easy to see that, calling h the strength of a Hertzian oscillator, then we must have the electrification e at any point $e = \frac{dh}{ds}$ while the current at the point must be that in the oscillator. Thus, if

$$e = e_0 \cos t \sin s,$$

we have

$$h = h_0 - e_0 \cos t \cos s,$$

and then, in order that the distribution of current may be greatest in the centre where $s = 0$, we must have the strongest Hertzian oscillator there, and consequently $h_0 = 0$. Applying similar considerations, any distribution can be built up, and Hertz's, *i.e.*, Maxwell's, equations applied to the case of large conductors, as, for example, to telephone circuits, alternating current circuits, and to the superficial conditions in reflection at metallic surfaces, or to calculate the force between two neighbouring Hertzian receivers, as in Mr. Boys's experiment.

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3. *Report of the Committee on Molecular Phenomena attending the Magnetisation of Iron.*—See Reports, p. 145.

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4. *Note on the Relation between the Diffusion of Motion and Propagation of Disturbance in some turbulent Liquid Motions. By* Professor G. F. FITZGERALD, *F.R.S.*

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5. *A Coefficient of Abrasion as an Absolute Measure of Hardness. By* F. T. TROUTON.

Mohs's scale of hardness, though probably affording all that is wanted by the practical mineralogist, can hardly be considered as very satisfactory from the physical point of view. The scale is constructed by the selection of a number of substances (ten in all) of unequal hardness, ranging from the softest to the hardest of ordinary minerals—from talc to diamond. The process of determining hardness ultimately resolves itself to finding by scratching the given substance with the selected minerals in turn whereabouts in the scale the substance stands. In this way hardness is said to be 4 or between 4 and 5, &c., according to the results of comparative operations.

One of the principal objections which has been urged to a method of this kind for measuring hardness is its being completely arbitrary, in so much as there can be no guarantee, that between successive numbers on the scale there is the same advance in hardness, whatever may be the proper meaning to be attached thereto. Thus it has been a subject of regret that, since this method is independent of all methods of measuring other quantities, there can obviously be no dimensional equation representing the dependence of the unit of hardness on the units of other physical quantities.

An altogether different way of measuring hardness suggested itself to me nearly two years ago, on seeing an apparatus which was constructed for the purpose of testing the durability of paving setts to traffic wear. In this apparatus a rotating iron or steel rubber (not unlike a pointless drill) was employed to wear away the stone, and in this way various stones could be compared by weighing the loss under similar circumstances. It occurred to me that an absolute scale of hardness might be invented, through the device of simply supposing each substance to be rubbed by itself, thus eliminating out the arbitrariness introduced into this method through the arbitrary selection of the material of the rubber.

In this way for various substances the amount worn off could be determined, on the passage at a certain velocity of two portions of the same kind of matter over each other, under a certain pressure. The ratio of what might be called the 'coefficient of abrasion' of two kinds of matter would then be the ratio of the losses under similar circumstances.

It seems highly probable that within wide limits this ratio would be independent of either the velocity or the pressure at which the comparisons were made; for it seems reasonable to suppose that in each case the weight abraded would be proportional, other things the same, to the pressure (from the laws of friction), similarly also to the velocity, for in each case the work done is so proportional. If this be assumed to be so, we have, at least, within wide limits, $m = \frac{vp\,at}{k}$, where m is the weight abraded over the area a under the pressure p in the time t, the surfaces having the relative velocity v, k being the necessary equating constant, and might be well called the coefficient of abrasion, or the 'absolute coefficient of hardness,' to distinguish it from Mohs's scale.

Thus the definition of 'absolute hardness' would be the reciprocal of the weight abraded over unit area under unit pressure in unit time, where the surfaces have relative unit velocity, or, combining the last two, per unit displacement.

The value of k taken should be the final one; that is to say, the process should go on sufficiently long so as to reach a constant stage. Also it is necessary to suppose that by some means the abraded material is removed as it is generated.

The total work may be divided into two parts—the heat generated and the work spent purely in disintegrating the material. It by no means follows, because the total work applied to produce a given displacement is proportional to the pressure, that the amount of material abraded is so proportional. For the parts may not always bear the same ratio to each other. However, within limits they probably do so, but the question, of course, is simply a matter for experiment.

Some preliminary experiments have been carried out with the object of investigating this, but the apparatus used, which was only a modification of the original plan, proved unsuitable. It, however, afforded encouragement to pursue the investigation further, and at present an apparatus is being constructed for the purpose.

The original plan consisted essentially of two cylinders of the material to be tested placed parallel, touching each other, which were to be rotated in the same direction, and to rub each other while being pressed together by a constant force. It is unnecessary to know the areas in contact, for the pressure being the force divided by the area, the area appears in both numerator and denominator.

On account of expense in construction this plan was modified in the experiments made, the second surface being stationary and always completely covered by the rotating cylinder. It was chiefly through this that the experiments were unsatisfactory, for the abraded material could not be removed from under the stationary surface, and a very fine powder, which acted as a lubricant, gradually collected. Were both surfaces to rotate, the cylinders could be continuously cleaned by brushes as they turned round.

It is easy to see that the dimensions of k are the same as that of the square of a velocity

$$K = [V^2] = [L^2T^{-2}]$$

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6. *The Effect of Direct and Alternating Pressures on the Human Body.*[1] *By* J. SWINBURNE.

A Wheatstone's bridge, which measured the resistance of the patient under various pressures, was made up. The alternating currents were measured with a non-inductive wattmeter arranged as an ammeter, the pressure being taken with a hot wire voltmeter. The tests were taken from hand to hand, the hands being dry, or wet with dilute acid in the case of direct currents, and dry in the case of alternating.

The maximum current taken was ·04 ampère by a subject whose resistance is low. He could have taken more if available. All the resistances are much lower

[1] *Electrician*, September 19, 1890.

than those obtained by the usual method of measuring with a bridge and one or two cells. Probably polarisation then interferes.

Out of the five subjects tested four could stand no more than 18 volts alternating, with a maximum effective current of ·03 ampère. The fifth took 54 volts and nearly a tenth of an ampère.

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7. *On the Use of Fluor Spar in Optical Instruments.*
By Professor SILVANUS P. THOMPSON, *D.Sc.*

The author referred to the existing uses of fluor spar for experiments on radiant heat, and in the 'apochromatic' microscope lenses of Zeiss. The latter application derives its importance from the extremely low dispersion—relatively to the mean refractive power—of the material. To these applications the author now added that of the construction of spectroscopic direct-vision prisms; and he described two prisms, both constructed for him by Mr. C. D. Ahrens, one consisting of a fluor prism cemented between two flint glass prisms, and a second consisting of one Iceland spar prism cemented between two fluor prisms. The former was considerably shorter than the ordinary direct-vision prism of equal power. The latter had the property of polarising the light, as well as dispersing it, and presented the novel feature of a true polari-spectroscope.

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8. *A new Direct-reading Photometer measuring from Unity to Infinity.*
By FREDERICK H. VARLEY.

This photometer was designed to meet the wants of electrical engineers and others. The conditions to be observed are that the instrument should be portable, have a range from one candle power to that of the electric arc, that the light to be measured and that of the standard should be exactly at the same distance from the screen. This instrument consists of two discs each pierced by two semi-ring-shaped windows or apertures; these extend to half a circle (180°); both are of the same width (1 inch). The openings in the two discs are placed in reverse positions to one another, so that if one half-ring is opened to its full extent (180°) the other half-ring is entirely closed; or, if the discs are shifted to an intermediate position, both apertures will be opened to an equal extent, namely, 90°. If in this position the discs are rotated it is obvious that an equal amount of light can pass through both rings; but, if the light to be measured is as one to seventeen candle-power, then the angular length of the two apertures must bear a proportionate ratio, in order that the two shadows shall be of equal density, and accordingly one aperture will be open to the extent of 10° for the brighter light, whilst that of the standard light is opened to 170°. Instead of dividing the circle into the usual 360°, the half-circle is divided into 2,000 parts, this giving a range from 1 to 1,999, or 2,000 in round numbers. By still further shifting the discs this aperture may be entirely closed, and read up to infinity. The divisions of the half-circle are numbered from left to right, and right to left, showing at once the fractional values of the angular extent of the opening, and thereby giving the value of the light.

In order to make the discs turn one upon the other, the author devised a modification of the Ferguson paradox; that is to say, the discs are carried by independent shafts, one of which is hollow, to allow the central axis to turn within it; at the end furthest from the discs a cog-wheel is fixed to each axis. By means of a sliding link the two wheels can be brought into gear with another axis, also provided with cog-wheels, each being of the same diameter, but one is cut with 100 teeth, whilst the other has 99 teeth; thus, upon rotating the discs, each revolution of the gearing wheels advances the discs, and so changes the proportion of the openings, one decreasing whilst the other increases, and *vice versâ*. This we can do until the two shadows are of equal density, or approximately so. The final adjustment is then made by hand. Behind the windows two hollow cones are placed, which have their axis directed to a point common to both, but at some distance in front of the discs, where the two shadows fall upon the screen. A second or back screen is then placed at the mouth of these cones, over which it fits and effectively cuts off one light from the other, so that on one side, say, is the electric light, on the other is the standard candle. The light from both passes through the axis of their respective cones, through the discs and on to the screen, upon which the shadow-image is cast.

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9. *On a Radiometric Record of Sun-heat from different parts of the Solar Disc. By* W. E. WILSON. *Communicated by* Professor G. F. FITZGERALD, *F.R.S.*

The author had represented, by means of a photograph curve, the variation of the effect on a radio-micrometer, 2mm. in diameter, as the image of the sun, 80 cm. in diameter, passed over the instrument. The curve is not a smooth one, and in the opinion of the author the cause of the unevenness lies in the uneven amount of radiation from the different parts of the sun's disc.

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10. *Recent Photographs of the less refrangible portions of Solar Spectrum under different Atmospheric Conditions. By* GEORGE HIGGS.

During the last few months the author has endeavoured to photograph under as many conditions as possible the atmospheric absorption regions of the solar spectrum. A number of results have been obtained within a few minutes after sunrise, some of which include the great A line at the extreme end of the visible red, and, judging from eye observations, it is supposed that this group is almost constant in intensity.

The photographs show, however, that it is quite as variable as the B line. The paper prints represent the head and portion of fluting, a few of the fainter lines are lost through under-development, but what may be photographed with a high sun, using the second order spectrum, is fairly represented.

Original negatives of a very low sun show the head as one broad line, whereas between forty and fifty may be counted with midday sun; a corresponding nebulosity broadens the lines composing the tail, which becomes irresolvable.

In about an hour after sunrise the thick band begins to break up in the region of the edge; the general nebulosity decreases but never disappears entirely, even with 12 o'clock sun.

The B group photographed under similar circumstances might easily be mistaken for that of A with a high sun, but the relative variability of the two lines is apparently the same, and has doubtless the same common origin.

I believe that Professor Liveing has shown both to be due to oxygen.

A sufficient number of photographs of these portions, together with those embracing little *a*, C, *a*, the so-called rain bands and atmospheric zones, w. l. 5,700, have been taken to show the existence of other sets of lines whose variation in intensity is still greater than that of A and B.

To complete the work in the regions referred to, other photographs are still required, and provision has been made to enable photographs to be taken during dry and frosty weather, to facilitate comparison by inspection with those already taken, where the quantity of aqueous vapour was considerable.

Some photographs of the invisible red, w. l. 8,350, will also show those lines which have a telluric origin.

Section B.—CHEMICAL SCIENCE.

President of the Section—Professor T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas.C.S.

THURSDAY, SEPTEMBER 4.

The President delivered the following Address:—

Leeds has one most notable association with chemistry of which she is justly proud. In the month of September 1767 Dr. Joseph Priestley took up his abode in this town. The son of a Yorkshire cloth-dresser, he was born in 1733 at Fieldhead, a village about six miles hence. His relatives, who were strict Calvinists, on discovering his fondness for books, sent him to the Academy at Daventry to be trained for the ministry. In spite of his poverty and of certain natural disadvantages of speech and manner, he gradually acquired, more especially by his controversial and theological writings, a considerable influence in Dissenting circles. A pressing invitation and the offer of one hundred guineas a year, induced him to accept an invitation to take charge of the congregation of Mill Hill Chapel here. He was already known to science by his 'History of Electricity,' and the effort was made to attach him still more closely to its cause by the offer of an appointment as naturalist to Cook's Second Expedition to the South Seas. But thanks to the intervention of some worthy ecclesiastics on the Board of Longitude who had the direction of the business, and who, as Professor Huxley once put it, 'possibly feared that a Socinian might undermine that piety which in the days of Commodore Trunnion so strikingly characterised sailors,' he was allowed to remain in Leeds, where, as he tells us in his Memoirs, he continued six years, 'very happy with a liberal, friendly, and harmonious congregation,' to whom his services (of which he was not sparing) were very acceptable. 'In Leeds,' he says, 'I had no unreasonable prejudices to contend with, and I had full scope for every kind of exertion.'[1]

We have every reason to feel grateful to the 'worthy ecclesiastics,' since their action indirectly occasioned Priestley to turn his attention to chemistry. The accident of living near a brewery led him to study the properties of 'fixed air,' or carbonic acid, which is abundantly formed in the process of fermentation, and which at that time was the only gas whose separate and independent existence had been definitely established. From this happy accident sprang that extraordinary succession of discoveries which earned for their author the title of the Father of Pneumatic Chemistry, and which were destined to completely change the aspect of chemical theory and to give it a new and unexpected development.

I have been led to make this allusion to Priestley, not so much on account of his connection with this place as for the reason that, as it seems to me, there has been a disposition to obscure his true relation to the marvellous development of chemical science which made the close of the last century memorable in the history of learning. Our distinguished fellow-worker, M. Berthelot, the Perpetual Secre-

[1] Leeds still enjoys one of the fruits of Priestley's insatiable power of work in her admirable Proprietary Library. He seems to have suggested its formation and was its first honorary secretary.

tary of the French Academy, has recently published, under the title of 'La Révolution Chimique,' a remarkable book, written with great skill, and with all the charm of style and perspicacity which invariably characterise his work, in which he claims for Lavoisier a participation in discoveries which we count among the chief scientific glories of this country. From the eminence of M. Berthelot's position in the world of science his book is certain to receive in his own country the attention which it merits, and as it is issued as one of the volumes of the Bibliothèque Scientifique Internationale it will probably obtain through the medium of translations a still wider circulation. I trust that I shall not be accused of being unduly actuated by what Mr. Herbert Spencer terms 'the bias of patriotism' in deeming the present a fitting occasion on which to bring these claims to your notice with a view of determining how far they can be substantiated.

All who are in the least degree familiar with the history of chemical science during the last hundred years will recognise, as I proceed, that the claims which M. Berthelot asserts on behalf of his illustrious predecessor are not put forward for the first time. Explicitly made, in fact, by Lavoisier himself, they were uniformly and consistently disallowed by his contemporaries. M. Berthelot now seeks to support them by additional evidence and to strengthen them with new arguments, and asks us thereby to clear the memory of Lavoisier from certain grave charges which lie heavily on it. You have doubtless anticipated that these claims have reference to Lavoisier's position in relation to the discovery of oxygen gas and the determination of the non-elementary nature of water.

The substance we now call oxygen—a name we owe to Lavoisier—was discovered by Priestley on August 1, 1774; he obtained it, as every schoolboy knows, by the action of heat upon the red oxide of mercury. We all remember the characteristically ingenuous account which Priestley gives of the origin of his discovery. M. Berthelot sees in it merely the evidence of the essentially empirical character of his work. 'Priestley,' he says, 'the enemy of all theory and of every hypothesis, draws no general conclusion from his beautiful discoveries, which he is pleased, moreover, not without affectation, to attribute to chance. He describes them in the current phraseology of the period with an admixture of peculiar and incoherent ideas, and he remained obstinately attached to the theory of phlogiston up to his death, which occurred in 1804' (p. 40). Such a statement is calculated to give an erroneous idea of Priestley's merit as a philosopher. That the implication it contains is wholly opposed to the real spirit of his work might be readily shown by numerous quotations from his writings. Perhaps this will suffice: 'It is always our endeavour, after making experiments, to generalise the conclusions we draw from them, and by this means to form a *theory* or system of principles to which all the *facts* may be reduced, and by means of which we may be able to foretell the result of future experiments.' This quotation is taken from the concluding chapter of his 'Experiments and Observations on Different Kinds of Air,' in which he actually seeks to draw 'general conclusions' concerning the constituent principles of the various gases which he himself made known to us and to show the bearing of these conclusions on the doctrine of phlogiston. That he was content to rest in the faith of Stahl's great generalisation, even to the end, is true, and the fact is the more remarkable when we recall the absolute sincerity of the man, his extraordinary receptivity, and, as he says of himself, his proneness 'to embrace what is generally called the heterodox side of almost every question.' If it is argued that this merely shows Priestley's inability to appreciate theory, it must be at least admitted that there is no proof that he was inimical to it. His position is clearly evident from the concluding words of the section of his work from which I have already quoted: 'This doctrine of the composition and decomposition of water has been made the basis of an entirely new system of chemistry, and a new set of terms has been invented and appropriated to it. It must be acknowledged that substances possessed of very different properties may, as I have said, be composed of the same elements in different proportions and different modes of combination. It cannot, therefore, be said to be absolutely *impossible* but that water may be composed of these two elements or any other. But then the supposition should not be admitted without *proof*; and if a former theory will sufficiently account for all the *facts* there is no occasion to have recourse to a new one, attended with no peculiar advantage (*loc. cit.* p. 543). . . . I should not feel much reluctance to adopt the *new doctrine*, provided any new and stronger evidence be produced for it. But though I have given all the attention that I can to the experiments of M. Lavoisier, &c., I think that they admit of the easiest explanation on the *old system*.' (*Loc. cit.* p. 563.)

The fact that Priestley was the first to consciously isolate oxygen is not contested by M. Berthelot, although he is careful to point out, what is not denied, that the exact date of the discovery depends on Priestley's own statement, and that his first publication of it was made in a work published in London in 1775. It was known before Priestley's famous experiment that the red oxide of mercury, originally formed by heating the metal in contact with air, would again yield mercury by the simple action of heat and without the intervention of any reducing agent. Bayen, six months before the date of Priestley's discovery, had observed that a gas was thus disengaged, but he gave no description of its nature, contenting himself merely by pointing out the analogy which his experiments appeared to possess to those of Lavoisier on the existence of an elastic fluid in certain substances. Afterwards, when the facts were established, Bayen drew attention to his earlier experiments, and claimed, not only the discovery of oxygen, but all that Lavoisier deduced from it. 'But,' says M. Berthelot, in reference to this circumstance, 'his contemporaries paid little heed to his pretensions, nor will posterity pay more' ('La Révolution Chimique,' p. 60).

M. Berthelot, however, does not dismiss Lavoisier's claims to a participation in the discovery in the same summary fashion. On the contrary, whilst not explicitly claiming for him the actual isolation, in the first instance, of oxygen, the whole tenor of his argument is to palliate, and even to justify, his demand to be regarded as an independent discoverer of the gas. He begins by asserting that Lavoisier had already a presentiment of its existence in 1774, and he quotes, in support of this assumption, an abstract from Lavoisier's memoir, published in December 1774, in the 'Journal de Physique' of the Abbé Rozier: 'This air, deprived of its fixable portion (by metals during calcination), is in some fashion decomposed, and this experiment would seem to afford a method of analysing the fluid which constitutes our atmosphere and of examining the principles of which it is composed. . . . I believe I am in a position to affirm that the air, as pure as it is possible to suppose it, free from moisture and from every foreign substance, far from being a simple body, or element, as is commonly thought, should be placed, on the contrary, . . . in the group of the mixtures, and perhaps even in that of the compounds.'

M. Berthelot further asserts that Lavoisier was at this time the first to recognise the true character of air, and he expresses his belief that it is probable that he would himself have succeeded in isolating its constituents if the path of inquiry had been left to him alone. It is no disparagement to Lavoisier's prescience to say that there is nothing in these lines, nor in the memoir of the repetition of Boyle's experiments on the calcination of tin to which they refer, to show that Lavoisier had made any advance beyond the position of Hooke and Mayow. It has been more than once pointed out that the chemists of the seventeenth century understood the true nature of combustion in air much better than their brethren of the last quarter of the eighteenth century. Hooke, in the 'Micrographia,' and Mayow, in his 'Opera Omnia Medicophysica,' indicated that combustion consists in the union of something with the body which is being burnt; and Mayow, both by experiment and inference, demonstrated in the clearest way the analogy between respiration and combustion, and showed that in both processes one constituent only of the air is concerned. He distinctly stated that, not only is there increase of weight attending the calcination of metals, but that this increase is due to the absorption of the same *spiritus* from the air that is necessary to respiration and combustion. Mayow's experiments are so precise, and his facts so incontestable, that, as Chevreul has said, it is surprising that the truth was not fully recognised until a century after his researches. (*Vide* Watts's 'Dictionary of Chemistry,' by Morley & Muir, art. 'Combustion,' p. 242.)

It is now necessary to examine Lavoisier's claims rather more closely and in the light of M. Berthelot's book. A *résumé* of his work 'On the Calcination of Tin' was given by Lavoisier to the Academy in November 1774, but the complete memoir was not deposited until May 1777. A careful comparison of an abstract of what was stated to the Academy in November 1774, contributed by Lavoisier himself, in December 1774, to the 'Journal de Physique' of the Abbé Rozier, makes it evident that very substantial additions were made to the communication before it was finally printed in the 'Mémoires de l'Académie des Sciences.' The possibility of this is allowed by M. Berthelot. He says (p. 58): 'A summary communication, often given *vivâ voce* to a learned society, such as the Academy of Sciences of Paris or the Royal Society of London, would immediately call forth verifications, ideas, and new experiments, which would develop the range and even the results of such communication. The original author, when printing his memoir, would in return—and for this he is hardly blamable—embody these additional results and later interpretations. It thus becomes most difficult to assign impartially to each his share in a rapid succession of discoveries.' (*Loc. cit.* p. 58.)

But although, as we shall see, Lavoisier was certainly aware of Priestley's great discovery, no allusion is made to the gas, nor to Priestley's previous work on the other constituent of air, which is printed in the 'Philosophical Transactions' for 1772, and for which he was awarded the Copley Medal by the Royal Society. It is simply impossible to believe that Lavoisier could have been uninfluenced by this work. Indeed, we venture to assert that the full and clear recognition of the non-elementary nature of air which he eventually made was based upon it. It is noteworthy that in the early part of his memoir he states his opinion that the addition not only of powdered charcoal, but of any phlogistic substance, to a metallic calx is attended with the formation of fixed air. It is certain that at this period he had not only not consciously obtained any gas resembling Priestley's dephlogisticated air from any calx with which he had experimented, but that none of his experiments had afforded him any idea that the gas absorbed during calcination was identical with it.

At Easter 1775 Lavoisier presented a memoir to the Academy 'On the Nature of the Principle which combines with Metals during Calcination.' This was '*relu le* 8 *août*, 1778.' To the memoir there is a note stating that the first experiments detailed in it were performed more than a year before; those on the red precipitate were made by means of *a burning glass* in the month of November 1774, and were repeated in the spring of 1775 at Montigny in conjunction with M. Trudaine. In this paper Lavoisier first distinctly announces that the principle which unites with metals during their calcination, which increases their weight, and which transforms them into calces, is nothing else 'than the purest and most salubrious part of the air; so that if that air which has been fixed in a metallic combination again becomes free, it reappears in a condition in which it is eminently respirable, and better adapted than the air of the atmosphere to support inflammation and the combustion of substances.' ('Œuvres de Lavoisier,' official edition, vol. ii. p. 123.) He then describes the method of preparing oxygen by heating the red oxide of mercury, and compares its properties with those of fixed air. There is, however, no mention of Priestley, nor any reference to his experiments. It can hardly be doubted that in this memoir Lavoisier intended his readers to believe that he was 'the true and first discoverer' of the gas which he afterwards named oxygen. This is borne out by certain passages in his subsequent memoir 'On the Existence of Air in Nitrous Acid; *lu le* 20 *avril*, 1776, *remis en décembre* 1777.' He had occasion incidentally to prepare the red oxide of mercury by calcining the nitrate, and says that he obtained from it a large quantity of an air 'much purer than common air, in which candles burnt with a much larger, broader, and more brilliant flame, and which in no one of its properties differed from that which *I* had obtained from the calx of mercury, known as *mercurius precipitatus per se*, and which Mr. Priestley had procured from a great number of substances by treating them with nitric acid.'

In another part of this memoir he says that 'perhaps, strictly speaking, there is nothing in it of which Mr. Priestley would not be able to claim the original idea; but as the same facts have conducted us to diametrically opposite results, I trust that, if I am reproached for having borrowed my proofs from the works of this celebrated philosopher, my right at least to the conclusions will not be contested.' M. Berthelot remarks on the irony of this passage: we may infer from it that the friends of the English chemist had not been altogether idle. In his memoir 'On the Respiration of Animals,' read to the Academy in 1777, he again appears to admit the claim of Priestley to at least a share in the discovery: 'It is known from Mr. Priestley's and my experiments that *mercurius precipitatus per se* is nothing but a combination' &c. In several subsequent communications Priestley's name is mentioned in very much the same connection, until we come to the classical memoir 'On the Nature of the Acids,' when it is said: 'I shall henceforth designate the dephlogisticated air, or the eminently respirable air . . . by the name of the *acidifying principle*, or, if it is preferred to have the same signification under a Greek word, by that of the "*principe oxygine*."'

In none of the memoirs after that of Easter 1775 is the claim for participation more than implied; it is made explicitly for the first time in the paper 'On a Method of Increasing the Action of Fire,' printed in the 'Mémoires de l'Académie' for 1782, and in these words: 'It will be remembered that at the meeting of Easter 1775 I announced the discovery, which I had made some months before with M. Trudaine,[1] in the laboratory at Montigny, of a new kind of air, up to then absolutely unknown, and which we obtained by the reduction of *mercurius precipitatus per se*. This air, which Mr. Priestley discovered at very nearly the same time as I, and I believe even before me, and which he had procured mainly from the combination of minium and of several other substances with nitric acid, has been named by him *dephlogisticated air*.'

In the 'Traité Elémentaire de Chimie' the claim for participation is again asserted in these words: 'This air, which Mr. Priestley, Mr. Scheele, and I discovered at about the same time . . . '

Now there is no question that Lavoisier knew of the existence of oxygen some months before he made the experiments with the burning glass of M. Trudaine at Montigny *for the simple reason that Priestley had already told him of it*. Priestley left Leeds in 1773 to become the librarian and literary companion of Lord Shelburne, and in the autumn of 1774 he accompanied his lordship on to the Continent, and spent the month of October in Paris. Lavoisier was famous for his hospitality; his dinners were celebrated; and Priestley, in common with every foreign *savant* of note who visited Paris at that period, was a welcome guest. What followed is best told in Priestley's own words: 'Having made the discovery [of oxygen] some time before I was in Paris, in the year 1774, I mentioned it at the table of Mr. Lavoisier, when most of the philosophical people of the city were present, saying that it was a kind of air in which a candle burnt much better than in common air, but I had not then given it any name. At this all the company, and Mr. and Mrs. Lavoisier as much as any, expressed great surprise. I told them I had gotten it from *precipitate per se* and also from *red lead*. Speaking French very imperfectly, and being little acquainted with the terms of chemistry, I said *plombe rouge*, which was not understood till Mr. Macquer said I must mean *minium*.'

In his account of his own work on dephlogisticated air, given in his 'Observations,' &c., 1790 edition, he further says, vol. ii. p. 108: 'Being at Paris in the October following [the August of 1774], and knowing that there were several very eminent chemists in that place, I did not omit the opportunity, by means of my friend Mr. Magellan,[2] to get an ounce of *mercurius calcinatus* prepared by Mr. Cadet, of the genuineness of which there could not possibly be any suspicion: and, at the same time, I frequently mentioned my surprise at the kind of air which

[1] M. Trudaine de Montigny died in 1777.

[2] Prof. Grimaux (Lavoisier, p. 51), says: 'Un de ses [Lavoisier's] amis qui habitait Londres, Magalhaens ou Magellan, de la famille du célèbre navigateur, lui envoyait tous les mémoires sur les sciences qui paraissaient en Angleterre et le tenait au courant des découvertes de Priestley.'

had got from this preparation to Mr. Lavoisier, Mr. le Roy, and several other philosophers, who honoured me with their notice in that city, and who, I dare say, cannot fail to recollect the circumstance.'

If any further evidence is required to prove that Lavoisier was not only not 'the true and first discoverer' of oxygen, but that he has absolutely no claim to be regarded even as a later and independent discoverer, it is supplied by M. Berthelot himself. Not the least valuable portion of M. Berthelot's book, as an historical work, is that which he devotes to the analysis of the thirteen laboratory journals of Lavoisier, which have been deposited, by the pious care of M. de Chazelles, his heir, in the archives of the Institute. M. Berthelot has given us a synopsis of the contents of almost every page of these journals, with explanatory remarks and dates when these could be ascertained. As he well says, these journals 'are of great interest because they inform us of Lavoisier's methods of work and of the direction of his mind—I mean the successive steps in the evolution of his private thought.' On the fly-leaf of the third journal is written, '*du* 23 *mars*, 1774, *au* 13 *février*, 1776.' From p. 30 we glean that Lavoisier visited his friend M. Trudaine at Montigny about ten days after his conversation with Priestley, and repeated the latter's experiments on the marine acid and alkaline airs (hydrochloric acid gas and ammonia). He is again at Montigny some time between the February 28 and the March 31, 1775, and repeats not only Priestley's experiments on the decomposition of mercuric oxide, presumably by means of M. Trudaine's famous burning glass, but also his observations on the character of the gas. The fly-leaf of the fourth journal informs us that it extends from February 13, 1776, to March 3, 1778. On p. 1 is an account of experiments made February 13 on 'précipité *per se* de chez M. Baumé,' in which the disengaged gas is spoken of as '*l'air déphlogistique de M. Prisley*' (*sic*). Such a phrase in a private notebook is absolutely inconsistent with the idea that at this time Lavoisier considered himself as an independent discoverer of the gas. How he came to regard himself as such we need not inquire. Nor is it necessary to occupy your time by any examination of the arguments by which M. Berthelot, with the skill of a practised advocate, would seem to identify himself with the case of his client. We would do him the justice of recognising the difficulty of his position. He seeks to discharge an obligation, of which the acknowledgment has been too long delayed. The Académie des Sciences a year ago awoke to the sense of its debt of gratitude to the memory of the man who had laboured so zealously for its honour, and even for its existence, during the stormy period of which France has just celebrated the centenary, and out of the *éloge* on Lavoisier which M. Berthelot, as Perpetual Secretary, was commissioned to deliver, has grown La Révolution Chimique. To write eulogy, however, is not necessarily to write history. We cannot but think that M. Berthelot has been hampered by his position, and that his opinion, or at least the free expression of it, has been fettered by the conditions under which he has written. We imagine we discern between the lines the consciousness that, to use Brougham's phrase, the brightness of the illustrious career which he eulogises is dimmed with spots which a regard for historical truth will not permit him wholly to ignore.

Two cardinal facts made the downfall of phlogiston complete—the discovery of oxygen and the determination of the compound nature of water. M. Berthelot's contention is that not only did Lavoisier effect the overthrow, but he also discovered the facts. In other words, he has not only a claim to a participation in the discovery of oxygen, but he is also 'the true and first discoverer' of the non-elementary nature of water. This second claim is directly and explicitly stated. Although it is supported by a certain ingenuity of argument, we venture to think that we shall be able to show it has no greater foundation in reality than the first.

Members of the British Association, who are at all familiar with its history, will recall the fact that this is not the first occasion on which the attempt to transfer 'those laurels which both time and truth have fixed upon the brow of Cavendish' has had to be resisted. At the Birmingham Meeting of 1839 the Rev. W. Vernon Harcourt, who then presided, devoted a large portion of his address to an able and eloquent vindication of Cavendish's rights. The attack came then as now from the Perpetual Secretary of the French Academy, and the charges were also formulated then, as now, in an *éloge* read before that learned body. The assailant was M. Arago, who did battle, not for his countryman Lavoisier, whose claims are dismissed as 'pretensions,' but on behalf of James Watt, the great engineer, who was one of the foreign members of the Institute.

It is not my wish to trouble you at any length with the details of what has come to be known in the history of scientific discovery as the Water Controversy—a controversy which has exercised the minds and pens of Harcourt, Whewell, Peacock, and Brougham in England; of Brewster, Jeffrey, Muirhead, and Wilson in Scotland; of Kopp in Germany; and of Arago and Dumas in France. This controversy, it has been said, takes its place in the history of science side by side with the discussion between Newton and Leibnitz concerning the invention of the Differential Calculus, and that between the friends of Adams and Leverrier in reference to the discovery of the planet Neptune. Up to now it has practically turned upon the relative merits of Cavendish and Watt. M. Berthelot is the first French *savant* of any note who has seriously put forward the claims of Lavoisier, his countryman and predecessor Dumas having deliberately rejected them.

At the risk of wearying you with detail, I am under the necessity of restating the facts in order to make the position clear. Some time before April 18, 1781, Priestley made what he called 'a random experiment' for the entertainment of a few philosophical friends. It consisted in exploding a mixture of inflammable air (presumably hydrogen) and common air, contained in a closed glass vessel, by the electric spark, in the manner first practised by Volta in 1776. The experiment was witnessed by Mr. John Warltire, a lecturer on natural philosophy and a friend of Priestley, who had rendered him the signal service of giving him the sample of the mercuric oxide from which he had first obtained oxygen. Warltire drew Priestley's attention to the fact that after the explosion the sides of the glass vessel were bedewed with moisture. Neither of the experimenters attached any importance to the circumstance at the time, Priestley being of opinion that the moisture was pre-existent in the gases, as no special pains were taken to dry them. Warltire, however, conceived the notion that the experiment would afford the means of determining whether heat was ponderable or not, and hence he was led to repeat it, firing the mixture in a copper vessel for greater safety. The results of these observations are contained in Priestley's 'Experiments and Observations on Air,' vol. v. 1781, App. p. 395.

At this period Cavendish was engaged on a series of experiments 'made, as he says, principally with a view to find out the cause of the diminution which common air is well known to suffer by all the various ways in which it is phlogisticated, and to discover what becomes of the air thus lost or condensed.' (Cavendish, 'Phil. Trans.' 1784, p. 119.) On the publication of Priestley's work he repeated Warltire's experiment, for, he says, as it 'seemed likely to throw great light on the subject I had in view, I thought it well worth examining more closely.' The series of experiments which Cavendish was thus induced to make, and which he made with all his wonted skill in quantitative work, led him some time in the summer of 1781 to the discovery that a mixture of two volumes of the inflammable air from metals (the gas we now call hydrogen) with one volume of the dephlogisticated air of Priestley combine together under the influence of the electric spark, or by burning, to form the same weight of water. If Cavendish had published the results of these observations at or near the time he obtained them, there would have been no Water Controversy. But in the course of the trials he found that the condensed water was sometimes acid, and the search for the cause of the acidity (which incidentally led to the discovery of the composition of nitric acid) occasioned the delay. The main result that a mixture of two volumes of inflammable air and one volume of dephlogisticated air could be converted into the same weight of water was, however, communicated to Priestley, as he relates in a paper in the 'Phil. Trans.' for 1783. Priestley was at this time interested in an investigation on the seeming convertibility of water into air, and he was led to repeat Cavendish's experiments, some time in March 1783, on what was apparently the converse problem. Priestley, however, made a fatal blunder in the repetition. With the praiseworthy idea of obviating the possibility of any moisture in the gases, he prepared the dephlogisticated air from nitre, and the inflammable air by heating what he calls 'perfectly made charcoal' in an earthenware retort. At this time, it must be remembered, there was no sharp distinction between the various kinds of inflammable air: hydrogen, sulphuretted hydrogen, marsh gas and olefiant gas, coal gas, the vapours of ether and turpentine, and the gas from heated charcoal, consisting of a mixture of carbonic oxide, marsh gas, and carbonic acid, were indifferently termed 'inflammable air.' Priestley attempted to verify Cavendish's conclusion on the identity of the weight of the gases used with that of the water formed; but his method in this respect, as in his choice of the inflammable air, was wholly defective, and could not possibly have given him accurate results. It consisted in wiping out the water from the explosion vessel by means of a weighed piece of blotting-paper and determining the increase of weight of the paper. He says, however: 'I always found as near as I could judge the weight of the decomposed air in the moisture acquired by the paper. . . . I wished, however, to have had a nicer balance for this purpose; the result was such as to afford a strong presumption that the air was reconverted into water, and therefore that the origin of it had been water.' These results, together with those on the conversion of water into air, were communicated towards the end of March 1783 by Priestley to Watt, who began to theorise upon them, and then to put his thoughts together in the form of a letter to Priestley, dated April 26, 1783, and which he requested might be read to the Royal Society on the occasion of the presentation of Priestley's memoir. In this letter Watt says: 'Let us now consider what obviously happens in the case of the deflagration of the inflammable and dephlogisticated air. These two kinds of air unite with violence, they become red-hot, and upon cooling totally disappear. When the vessel is cooled, a quantity of water is found in it equal to the weight of the air employed. This water is then the only remaining product of the process, and *water, light*, and *heat* are all the products. *Are we not then authorised to conclude that water is composed of dephlogisticated air and phlogiston deprived of part of their latent or elementary heat; that dephlogisticated or pure air is composed of water deprived of its phlogiston and united to elementary heat and light, &c.?*'

This letter, although shown to several Fellows of the Society, was not publicly read at the time intended. Priestley, before its receipt, had detected the fallacy of his experiments on the seeming conversion of water into air, and as much of the letter was concerned with this matter Watt requested that it should be withdrawn. Watt, however, as he tells Black[1] in a letter dated June 23, 1783, had not given up his theory as to the nature of water, and on Nov. 26, 1783, he restated his views more fully in a letter to De Luc. In the meantime Cavendish, having completed one section of his investigation, sent in a memoir to the Royal Society, which was read on January 15, 1784, in which he gives an account of his experiments and announces his conclusion 'that dephlogisticated air is in reality nothing but dephlogisticated water, or water deprived of its phlogiston; or, in other words, that water consists of dephlogisticated air united to phlogiston; and that inflammable air is either pure phlogiston, as Dr. Priestley and Mr. Kirwan suppose, or else water united to phlogiston.' Watt thereupon requested that his letter to De Luc should be published, and it was accordingly read to the Royal Society on April 29, 1784. Which of the two—Cavendish or Watt—is, under these circumstances, to be considered as 'the true and first discoverer' of the compound nature of water is the question which has been hitherto the main subject of the water controversy.

Let us now consider the matter as it affects Lavoisier. In 1783 Lavoisier had publicly declared against the doctrine of phlogiston, or rather, as M. Dumas puts it, 'against the crowd of entities of that name which had no quality in common except that of being intangible by every known method.' ('Leçons sur la Philosophie Chimique,' p. 161.) How completely Lavoisier had dissociated himself from the theory may be gleaned from his memoir of that year. 'Chemists,' he says, 'have made a vague principle of phlogiston which is not strictly defined, and which in consequence accommodates itself to every explanation into which it is pressed.

[1] Watt, *Correspondence*, p. 31.

Sometimes this principle is heavy and sometimes it is not; sometimes it is free fire and sometimes it is fire combined with the earthy element; sometimes it passes through the pores of vessels and sometimes they are impenetrable to it: it explains at once causticity and non-causticity, transparency and opacity, colours and the absence of colours. It is a veritable Proteus which changes its form every moment.'

But Lavoisier had merely renounced one fetich for another. At the time that he penned these lines he was as much under the thraldom of *le principe oxygine* as the most devoted follower of Stahl was in the bondage of phlogiston. The idea that the calcination of metals was but a slow combustion had been fully recognised. M. Berthelot tells us that as far back as the March of 1774 Lavoisier had written in his laboratory journal: 'I am persuaded that the inflammation of inflammable air is nothing but a fixation of a portion of the atmospheric air, a decomposition of air. . . . In that case in every inflammation of air there ought to be an increase of weight,' and he tried to ascertain this by burning hydrogen at the mouth of a vessel from which it was being disengaged. In the following year he asks, what remains when inflammable air is burnt completely? According to the theory by which he is now swayed it should be an acid, and he made many attempts to capture this acid. In 1777 he and Bucquet burnt six pints of the inflammable air from metals in a bottle containing lime-water, in the expectation that fixed air would be the result. And in 1781 he repeated the experiment with Gengembre, with the modification that the oxygen was caused to burn in an atmosphere of hydrogen, but not a trace of any acid product could be detected. Of course there must have been considerable quantities of water formed in these experiments, but Lavoisier was preoccupied with the conviction that oxidation meant acidification, and its presence was unnoticed, or, if noticed, was unheeded. Macquer, in 1776, had drawn attention to the formation of water during the combustion of hydrogen in air, but Lavoisier has stated that he was ignorant of that observation. What was it, then, that put him on the right track? We venture to think that M. Berthelot has himself supplied the answer. He says (p. 114): 'Rumours of Cavendish's trials had spread throughout the scientific world during the spring of 1783. . . . Lavoisier, always on the alert as to the nature of the products of the combustion of hydrogen, was now in such position that the slightest hint would enable him to comprehend its true nature. He hastened to repeat his trials, as he had the right to do, never having ceased to occupy himself with a question which lay at the very heart of his doctrine.'

'On the 24th of June, 1783,' continues M. Berthelot, 'he repeated the combustion of hydrogen in oxygen, and he obtained a notable quantity of water without any other product, and he concluded from the conditions under which he had worked that the weight of the water formed could not be other than equal to that of the two gases which had formed it. The experiment was made in the presence of several men of science, among whom was Blagden, a member of the Royal Society of London, who on *this occasion* recalled the observations of Cavendish (*qui rappela à cette occasion les observations de Cavendish*).'

On the following day Lavoisier published his results. The following is the official minute of the communication taken from the register of the sittings of the Académie des Sciences:—

Meeting of Wednesday, June 25, 1783.

MM. Lavoisier and De Laplace announced that they had lately repeated the combustion of Combustible Air with Dephlogisticated Air; they worked with about 60 *pints of the airs, and the combustion was made in a closed vessel: the result was very pure water.*

The cautious scribe who penned that minute did not commit himself too far. M. Berthelot, however, regards it as the first certain date of publication, established by authentic documents, in the history of the discovery of the composition of water; 'a discovery,' he adds, 'which, on account of its importance, has excited the keenest discussion.'

You will search in vain through the laboratory journals, as given by M.

Berthelot, for any indications either of experiments or reflections which would enable you to trace the course of thought by which Lavoisier was guided to the truth. There is absolutely nothing on the subject until in the eighth volume (25 *mars*, 1783, *au février* 1784), and on p. 63 we come to the experiment of June 24, and we read: 'In presence of Messieurs Blagden, of [name illegible], de Laplace, Vandermonde, de Fourcroy, Meusnier, and Legendre, we have combined in a bell-jar dephlogisticated air and inflammable air drawn from iron by means of sulphuric acid &c. . . . The amount of water may be estimated at 3 drachms: the amount which should have been obtained was 1 ounce 1 drachm and 12 grains. Thus we must suppose that there was a loss of two-thirds of the amount of the air or that there has been a loss of weight.'

And this is the experiment which, according to M. Berthelot, enabled Lavoisier to conclude that 'the weight of the water formed could not be other than equal to that of the two gases which had formed it!' It is on this single experiment, hurriedly and imperfectly done, that Lavoisier's claim to the discovery of the compound nature of water is based! M. Berthelot objects to the assumption that it was hurriedly done. He says, on p. 114: 'Lavoisier caused a new apparatus to be made, with a couple of tubes and two reservoirs for the gases; an arrangement which would require a certain amount of time to put together; this circumstance proves that it could not have been an improvised trial.' To what extent it was improvised will be seen immediately.

Now although the laboratory journals do not in this case 'inform us of Lavoisier's methods, and of the direction of his mind . . . the successive steps in the evolution of his private thought,' we have other means of ascertaining how he arrived at his knowledge. The method was simplicity itself: he *was told of the fact, and his informant was none other than Cavendish's assistant, Blagden.*

Cavendish's memoir was published in 1784. Before it was struck off its author caused the following addition to be made: 'During the last summer also a friend of mine gave some account of them [the experiments] to M. Lavoisier, as well as of the conclusion drawn from them, that dephlogisticated air is only water deprived of phlogiston; but at that time so far was M. Lavoisier from thinking any such opinion warranted that, till he was prevailed upon to repeat the experiment himself, he found some difficulty in believing that nearly the whole of the two airs could be converted into water.' This addition, as I have had the opportunity of verifying by an inspection of the original MS. in the archives of the Royal Society, was made in the handwriting of Cavendish's assistant and amanuensis, Blagden.

When Lavoisier's memoir appeared it was found to contain the following reference to this circumstance: 'It was on the 24th of June that M. de Laplace and I made this experiment in presence of MM. le Roi, Vandermonde, and several other Academicians, and of Mr. Blagden, the present Secretary of the Royal Society of London. The latter informed us (*ce dernier nous apprit*) that Mr. Cavendish had already tried, in London, to burn inflammable air in closed vessels, and that he had obtained a very sensible quantity of water.'

This reference was so partial, and its meaning so ambiguous, that Blagden addressed the following letter to Crell to be published in his 'Chemische Annalen' (Crell's 'Annalen,' 1786, vol. i. p. 58).

It is so direct and conclusive that I offer no apology for giving it almost entire:—[1]

I can certainly give you the best account of the little dispute about the first discoverer of the artificial generation of water, as I was the principal instrument through which the first news of the discovery that had been already made was communicated to Mr. Lavoisier. The following is a short statement of the history:—

In the spring of 1783 Mr. Cavendish communicated to me, and other members of the Royal Society, his particular friends, the result of some experiments with which he had for a long time been occupied. He showed us that out of them he must draw the conclusion that

[1] Mr. Muirhead's translation. *Vide* Watt, *Correspondence*, 'Composition of Water,' p. 71.

dephlogisticated air was nothing else than water deprived of its phlogiston; and, *vice versâ*, that water was dephlogisticated air united with phlogiston. About the same time the news was brought to London that Mr. Watt, of Birmingham, had been induced by some observations to form a similar opinion. Soon after this I went to Paris, and in the company of Mr. Lavoisier and of some other members of the Royal Academy of Sciences I gave some account of these new experiments and of the opinions founded upon them. They replied that they had already heard something of these experiments, and particularly that Dr. Priestley had repeated them. They did not doubt that in such manner a considerable quantity of water might be obtained, but they felt convinced that it did not come near to the weight of the two species of air employed, on which account it was not to be regarded as water formed or produced out of the two kinds of air, but was already contained in and united with the airs, and deposited in their combustion. This opinion was held by Mr. Lavoisier, as well as by the rest of the gentlemen who conferred on the subject; but, as the experiment itself appeared to them very remarkable in all points of view, they unanimously requested Mr. Lavoisier, who possessed all the necessary preparations, to repeat the experiment, on a somewhat larger scale, as early as possible. This desire he complied with on the 24th June, 1783 (as he relates in the latest volume of the Paris memoirs). From Mr. Lavoisier's own account of his experiment, it sufficiently appears that at that period he had not yet formed the opinion that water was composed of dephlogisticated and inflammable airs, for he expected that a sort of acid would be produced by their union. In general, Mr. Lavoisier cannot be convicted of having advanced anything contrary to truth; but it can still less be denied that he concealed a part of the truth; for he should have acknowledged that I had, some days before, apprised him of Mr. Cavendish's experiments, instead of which the expression 'il nous apprit' gives rise to the idea that I had not informed him earlier than that very day. In like manner Mr. Lavoisier has passed over a very remarkable circumstance, namely, that the experiment was made in consequence of what I had informed him of. He should likewise have stated in his publication not only that Mr. Cavendish had obtained 'une quantité d'eau très sensible,' but that the water was equal to the weight of the two airs added together. Moreover, he should have added that I had made him acquainted with Messrs. Cavendish and Watt's conclusions, namely, that water, and not an acid, or any other substance, arose from the combustion of the inflammable and dephlogisticated airs. But *those* conclusions opened the way to Mr. Lavoisier's present theory, which perfectly agrees with that of Mr. Cavendish, only that Mr. Lavoisier accommodates it to his old theory, which banishes phlogiston. . . . The course of all this history will clearly convince you that Mr. Lavoisier (instead of being led to the discovery by following up the experiments which he and Mr. Bucquet had commenced in 1777) was induced to institute again such experiments, solely by the account he received from me, and of our English experiments, and that he really discovered nothing but what had before been pointed out to him to have been previously made out and demonstrated in England.

To this letter, reflecting so gravely on his honour and integrity, Lavoisier made no reply. Nor did Laplace, Le Roi, Vandermonde, or any one of the Academicians concerned vouchsafe any explanation. *De non apparentibus et de non existentibus eadem ratio.* No explanation appeared, because none was possible. M. Berthelot ignores this letter, which is the more remarkable, since reference is made to it in more than one of the publications which he tells us he has consulted in the preparation of his account of the Water Controversy. If he knew of it he must regard it either as unworthy of an answer or as unanswerable.

It would be heaping Ossa on Pelion to adduce further evidence from letters of the time of what Lavoisier's contemporaries thought of his claims. *De mortuis nil nisi bonum.* I would much more willingly have dwelt upon the virtues of Lavoisier, and have let his faults lie gently on him; but I have felt it incumbent on me on this occasion to make some public answer to M. Berthelot's book, and in no place could that answer be more fittingly given than in this town which saw the dawn of that work out of which these grand discoveries arose. It may be that much of what I have had to say is as a twice-told tale to many of you. I trust I need make no apology on that account. The honour of our ancestors is in our keeping, and we should be unworthy of our heritage and false to our trust if we were slow to resent or slack to repel any attempt to rob them of that glory which is their just right and our proud boast.

The following Reports and Papers were read:—

1. *Report of the Committee on recent Inquiries into the History of Chemistry.*

[A Report will be presented at the next meeting of the Association.]

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2. *Report of the Committee on the Silent Discharge of Electricity in Gases.*

See Reports, p. 338.

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3. *Report of the Committee on the present Methods of Teaching Chemistry.*

See Reports, p. 265.

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4. *On Recent Legislation as Facilitating the Teaching of Science. By* Sir HENRY ROSCOE, *M.P., F.R.S.*

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5. *The Refraction and Dispersion of Fluorbenzene and Allied Compounds. By* J. H. GLADSTONE, *Ph.D., F.R.S., and* GEORGE GLADSTONE.

The authors had determined the molecular refraction of very pure specimens of fluor-, chloro-, bromo-, and iodo- benzene for the solar lines ACDEGH. The compounds of the three more common halogens gave the following results for chlorine, bromine, and iodine:—

Chlorine	$R_A = 10{\cdot}00$,	$R_{H-A} = 0{\cdot}70$
Bromine	,, $= 15{\cdot}23$,	,, $= 1{\cdot}41$
Iodine	,, $= 25{\cdot}20$,	,, $= 3{\cdot}43$

These are in conformity with numbers previously determined for the halogens, especially when deduced from such bodies as bromoform, dibromide of ethylene, &c. In the case of the fluoride the molecular refraction is exceedingly small, and smaller for each successive line of the spectrum; so that for

$$\text{Fluorine } R_A = +0{\cdot}63, R_{H-A} = -0{\cdot}28$$

This small molecular refraction is also in accordance with what was previously known; but a negative dispersion of the same character has never before been observed. Upon examining, however, the refraction of fluorspar and aqueous solutions of fluoride of potassium, the fluorine in them was found to exhibit the same reversal. The double fluosilicates examined by Topsoe and Christiansen also appear to lead to the same inference, though the data for exact calculation are wanting.

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6. *A Method of Quantitative Analysis. By* G. H. BAILEY, *D.Sc., Ph.D., and* J. C. CAIN.

The method consists in precipitating in the ordinary manner, and weighing the precipitate in the liquid, having previously determined its specific gravity. The specific gravity of the liquid and of the precipitate being known, and the volume of the flask in which the weighing is made, it is possible to calculate the weight of the precipitate directly, avoiding the troublesome operations of filtering and washing.

It is not necessary to wash the precipitate free from the supernatant liquor, since, by having two flasks of, say, 100 c.c. content, and filling one with the supernatant liquor, and the other with supernatant liquor and precipitate, and then determining the weight of both, we have all the data required. The 100 c.c. flasks as ordinarily made for volumetric analysis are too wide in the neck to admit of accuracy, and flasks having narrow necks with graduations were used in the experiments. Special arrangements were also made to overcome the difficulty of introducing the liquids and precipitate through a neck of such small diameter.

The method is specially recommended for commercial analyses where a tolerably large quantity of the sample to be determined is available, and the amount taken should be such as to yield not less than 5 grammes of precipitate. A manifest objection that might be raised to such a process is that the specific gravity of the precipitate varies according to the circumstances under which precipitation occurs.

A number of details are given in the paper dealing with this point. A great advantage of the method is the saving of time, especially where a series of determinations of a similar character have to be made.

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7. *The Behaviour of the More Stable Oxides at High Temperatures. By* G. H. Bailey, *D.Sc., Ph.D., and* A. A. Read.

This is a continuation of the work already published on the behaviour of oxide of copper. The oxides which have now been submitted to the action of the oxidising flame of an oxy-coal-gas jet are the most stable of the oxides of lead—bismuth, tin, vanadium, antimony, uranium, molybdenum, and tungsten. Of these, vanadium pentoxide, antimony tetroxide, and molybdenum trioxide undergo decomposition, yielding respectively vanadium trioxide (which readily oxidises on exposure to tetroxide), antimony trioxide, and the blue oxide of molybdenum respectively. The other oxides appear to undergo no change of composition, excepting in the case of tin, where a slight loss of oxygen occurs.

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8. *The Spectra of the Haloid Salts of Didymium. By* G. H. Bailey, *D.Sc., Ph.D.*

The observations, of which a *résumé* is given, were commenced some years ago, and a communication made upon the earliest results at the Southport Meeting by Professor Schuster, in conjunction with the present author. The observations made may be classified into qualitative and quantitative, according as they deal with a change in the *appearance* of the absorption-bands, or in their *position*.

Crystals of the chloride having been prepared, they were subjected to examination, under ordinary light and under polarised light, in such a way that the plane of polarisation was parallel to the ortho- and klino-diagonal of the crystal respectively. No change in the position of the bands was observed, but there were marked differences in intensity of several of the bands under each of these conditions. In like manner, the effect of the presence of reagents in solutions of the salts on the position or character of the bands was studied. Nitric acid was found to increase the intensity of certain bands and diminish that of others; so that in its presence the character of the spectra is much altered. Other strong acids had little effect. Thus far the results are of a qualitative nature. When, however, a comparison was made of the spectra of the chloride, bromide, and iodide of didymium, it was found that the bands of these salts presented a general similarity in character, but occupied different positions: those of the bromide being nearer the red, and those of the iodide being nearer the violet, than in the case of the chloride.

Moreover, the bands of the solution of the chloride were displaced to the violet side of the crystal, so that they occupied approximately the same position as those of the crystalline iodide. Finally, *equal* displacement of all the bands did not occur; and there appeared in these quantitative measurements, as also in the case where nitric acid was added, a selective action, so that certain bands underwent greater displacement or alteration than others. These point to the compound nature of didymium, and show some relation to its proximate constituents, praseo- and neo-didymium.

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9. *On the Condition of the Air in Public Places of Amusement, with special reference to Theatre Hygiene. By* W. Hepworth Collins, *F.C.S., F.R.M.S.*

The principal theatres in Manchester were taken as types of well-arranged English theatres. Samples of air were taken at stated periods during the performances in the months of December 1889 and January 1890. Duplicate samples were analysed in all cases, and samples of the air outside the theatre were taken simultaneously for the purpose of comparison. The examination of the samples was confined to the estimation of—(1) carbonic acid (by Pettenkofer's method); (2) organic matter (by Carnelley's method, 'Proc. Roy. Soc.' xli. 238); and

(3) micro-organisms (by Hesse's method, 'Mittheilungen aus dem kaiserlichen Gesundheitsamte,' ii. 182).

The results are contained in the following tables:—

A.—*Comedy Theatre, Manchester.*

Place	Time	Temperature. F.	Carbonic Acid per 10,000vols	Organic Matter per cent.	Bacteria per c.c.	Moulds per c.c.	Total Micro-organisms
	p.m.	°					
Stalls . .	6.30	53	6·2	14·6	6	34	40
" . .	9.0	71	9·6	34·2	29	41	70
Pit . .	9.40	96	11·3	60·4	36	39	75
" . .	10.5	103	13·9	63·1	69	104	173
Gallery . .	8.5	90	12·1	49·0	34	20	54
" . .	9.5	116	12·6	56·3	45	45	90
Peter Street, outside the Theatre	6.30	36	5·1	16·6	25·3	63	89
	9.0	36	5·0	16·9	26·9	106	140
	9.40	37	5·1	16·6	40·6	64	116
	10.5	37	5·2	17·1	109	103	214
	8.5	36	5·2	26·9	26	41	73
	9.5	36	5·3	16·9	26	40	66

B.—*Theatre Royal, Manchester.*

Place	Time	Temperature. F.	Carbonic Acid per 10,000vols	Organic Matter per cent.	Bacteria per c.c.	Moulds per c.c.	Total Micro-organisms
	p.m.	°					
Pit . .	7.45	69	12·6	69·5	60	60	120
" . .	8.15	100	14·1	70·0	65	69	134
Gallery . .	8.30	121	16·9	105	96	106	202
" . .	9.30	116	16·5	109	97	120	217
Circle . .	9.30	95	12·3	46	29	11	40
" . .	10.0	90	11·3	69	36	41	77
Peter Street, outside the Theatre	7.45	39	4·9	16·9	26	40	66
	8.15	39	4·9	17·4	31	36	67
	8.30	36	5·3	17·9	39	30	69
	9.30	33 }	5·6	26·9	45	60	105
	9.30	33 }					
	10.0	35	5·9	63·6	69	100	169

C.—*Princes Theatre, Manchester.*

Place	Time	Temperature. F.	Carbonic Acid per 10,000vols	Organic Matter per cent.	Bacteria per c.c.	Moulds per c.c.	Total Micro-organisms
	p.m.	°					
Pit . .	7.45	67	11·3	60·5	16	26	42
" . .	9.0	104	13·0	106	69	43	112
Circle . .	8.0	73	10·9	49	40	6	46
" . .	10.0	90	14·0	109	26	90	116
Gallery . .	7.45	94	14·6	116	60	40	100
" . .	10.0	116	17·3	206	143	51	194
Peter Street, outside the Theatre	7.45	39	5·6	16·5	29	6	35
	9.0	40	5·0	17·3	20	9	29
	8.0	37	4·9	17·9	25	41	66
	10.0	32	4·6	16·9	6	51	57
	7.45	39	5·1	40·3	15	11	26
	10.0	30	5·0	40·9	12	14	26

FRIDAY, SEPTEMBER 5.

The following Reports and Papers were read :—

1. *Report on Isomeric Naphthalene Derivatives.*

[The report is deferred for completion.]

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2. *The Development of the Coal-tar Colour Industry since* 1882.[1] *By* W. H. PERKIN, *Ph.D., F.R.S.*

In the brief report given, the first development since 1882 referred to was that of the synthetical formation of colouring-matters of the para-rosaniline group by means of tetramethyl diamido-benzophenone, produced by dimethylaniline and phosgene gas, and the formation from that body of hexamethyl para-rosaniline, Victoria blue, &c., also auramine. Reference was then made to the group of phthaleïns, as cœruleïn, galleïne, fluoresceïne, and more especially to the beautiful new colouring-matter derived from meta-amidophenol and phthalic anhydride, *rhodamine,* its relationship to fluoresceïne being shown. The rhodamine derived from meta-amidophenol and succinic anhydride was also referred to. In the alizarine series it was mentioned that this group of colouring-matters had been speedily increasing in consumption, chiefly in the woollen trade, and that the isomer of purpurin, anthragallol, made synthetically, had been added to this list of colouring-matters. Alizarine blue in its soluble state, when combined with bisulphate of sodium, was also more appreciated as a substitute for indigo. Some peculiar derivatives of alizarine blue, known as *alizarine green* and *alizarine indigo blue,* had also lately been introduced. For the purpose of producing a great variety of shades of grey, slate, drab, olive, brown, black, &c., along with alizarine colours, some products not belonging to the alizarine series, such as *galloflavine* and *naphthazarine,* had also come into use. Amongst the yellow dyes there have also been several additions, as *quinoline yellow,* and some oxyketones produced from benzoic acid and pyrogallol, as 'alizarine yellow A,' *trioxybenzophenone,* and 'alizarine yellow C,' which is *gallacetophenone.* Also *tartrazine,* a product obtained from dioxytartaric acid and phenylhydrazine monosulphonic acid. Great improvements have also been made in the preparation of methylene blue, by which the yield of colouring-matters has been increased, with a corresponding cheapening of its cost.

With respect to the azo colours, their manufacture has attained colossal proportions, and their purity has reached a great state of perfection.

The next series of colouring-matters mentioned was the remarkable class of compounds known as *substantive* dyes—colouring-matters which unite with cotton fibre without the intervention of a mordant; the number of these discovered during the last few years places at the disposal of the dyer yellow, red, purple, blue, and other colouring-matters of this class.

As to the annual value and cost of the coal-tar colouring-matters now made, it is found difficult to get a correct estimate. In 1882 it was thought to be about 3,350,000*l.*; but the large increase of weight of colouring-matters produced since that time, it was believed, had been fully compensated by a corresponding reduction of their selling-price.

Germany still holds the first position in this industry, though competition of Swiss, French, and English manufacturers with that country has been steadily increasing. The use of the precise methods of scientific research in this industry, especially in Germany, and the consequent improvement in quality and yield of colouring-matter, with diminished cost, showed the great importance of manufacturing under these circumstances, and it was hoped that chemical manufacturers of this country would profit by their example, and, by having good laboratories in

[1] Published in *Industries,* September 26 and October 3, 1890.

their works, occupied by highly-skilled chemists, would raise the chemical industries of the country to the highest state of perfection.

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3. *Behaviour of Copper Potassium Chloride and its Aqueous Solutions at different Temperatures. By* J. H. Van 't Hoff.

When the blue crystalline double chloride of copper and potassium ($CuCl_2$, 2KCl, $2H_2O$) is heated to 100° C. it changes colour, and can be seen to be decomposed into three constituents—water, small cubical crystals of potassium chloride, and reddish-brown needles of a new double salt ($CuCl_2$, KCl). This double salt may also be prepared by gently heating the blue double salt with excess of cupric chloride; thus:—

$$CuCl_2,\ 2KCl,\ 2H_2O + CuCl_2,\ 2H_2O = 2CuCl_3K + 4H_2O.$$

Both these changes are reversible, and take place at fixed temperatures, which were determined by noting the change of volume of the mixtures in a dilatometer. The first change was found to take place at 93° C., the second at 56° C.

The solubility of all the salts concerned was carefully examined, and the vapour-pressures of the different solutions were determined simultaneously in a manometer with four branches.

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4. *Report of the Committee on the Action of Light on the Hydracids of the Halogens in presence of Oxygen.*—See Reports, p. 263.

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5. *Experiments on the Combustion of Gases under Pressure. By* Professor Liveing, *F.R.S., and* Professor Dewar, *F.R.S.*

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6. *On the Rate of Explosion of Hydrogen and Chlorine in the Dry and Moist States.*[1] *By* Professor H. B. Dixon, *F.R.S., and* J. A. Harker.

The authors have previously shown (confirming Pringsheim's experiments) that a mixture of hydrogen and chlorine in a thoroughly dried state is far less sensitive to explosion by light than when the gases are moist. The authors have now determined the rate of the 'explosion-wave' of hydrogen and chlorine in the dried and in the moist states. The gases were fired by an electric spark, and the measurement was begun at a distance of 4 feet from the firing-point. The mean rate for the dried gases is slightly *faster* than that for the moist gases, a fact which points to the direct combination of hydrogen and chlorine under these conditions without the interaction of water.

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7. *On the Ignition of Explosive Gaseous Mixtures. By* G. S. Turpin, *B.A., D.Sc.*

The author has commenced a thorough investigation of the conditions affecting the ignition of explosive mixtures of gases, and the present paper gives an account of the results obtained in a series of experiments on the temperatures of ignition of various mixtures of CS_2 vapour with oxygen and other gases.

Davy was the earliest investigator of the subject, but his method, which was to observe the effect of plunging a heated rod of iron into a jar containing the gaseous mixture, could not lead to any definite results. This same method was afterwards applied by Frankland, and, with considerable improvements, by Wüllner and O. Lehmann. A far better apparatus was described by A. Mitscherlich in 1877, but apparently he did not carry out the investigation he had planned. The principle of this apparatus is the same as the first one used by Mallard and Le Châtelier a

[1] Published *in extenso* in the *Memoirs of the Manchester Lit. and Phil. Soc.*, 1890–1.

few years later, and consists in passing the mixture through a water-valve into a tube heated to a known temperature. But Mallard and Le Châtelier's second method is a still further improvement. In this they introduce the mixture into a heated and exhausted bulb. This is the method which, with some modifications, is employed by the author.

Davy found that slow combustion goes on at temperatures considerably below that at which the mixture takes fire. The existence of a discontinuity between this gradual combustion and ignition proper is assumed by the phrase 'temperature of ignition.' The author shows that such a discontinuity does really exist in some cases, while in others, especially in mixtures containing a large proportion of an inert gas, there is a perfect gradation from the slow combination through a combination lasting many seconds and attended only by a faint glow up to practically instantaneous combination accompanied by a bright flame. The discontinuity is explained as due to the effect of the heat produced by the slow combustion of the mixture in raising the temperature of the gases above that of the bulb into which they have been introduced. In accordance with this explanation the temperature of ignition is higher in a narrow tube than in one of larger diameter. With most mixtures ignition takes place at temperatures not much above the minimum temperature only after the lapse of a period of delay which may amount to thirty seconds or more. During this interval it is supposed that the temperature of the mixture is being raised above that of the tube by slow combination. At the same time that the temperature of the mixture is raised its composition is also altered by the slow combustion, and these two effects oppose one another. In some mixtures this change of composition brings about the extinction of the combustion unless it be rapid at the commencement, and then the phenomenon of a delay in the ignition is not observed.

The slow combustion of CS_2 is perceptible at 100°, and is comparatively rapid at 130°. It is attended by the production of a reddish-brown solid, which is deposited on the sides of the tubes, and also issues as a finely-divided smoke with the gaseous products of combustion. This powder contains both carbon and sulphur, but its composition has not yet been thoroughly made out. SO_2 is produced in abundance, but very little, if any, CO_2 or CO.

The temperature at which the slow combustion develops into ignition varies considerably with the composition of the mixture. It is lowest for mixtures containing a large excess of oxygen, and is raised distinctly by the addition of nitrogen or carbon dioxide, but much more by addition of sulphur dioxide. This will be seen from the following table giving the temperatures of ignition in a tube of 5 mm. internal diameter:—

$CS_2 + 10O_2$	160°
$CS_2 + 5O_2 + 5N_2$	175°
$CS_2 + 2O_2 + 8N_2$	290°
$CS_2 + 5O_2 + 5CO_2$	175°
$CS_2 + 5O_2 + 5SO_2$	260°

The effect of change of pressure on the ignition was also examined, and found to be somewhat complex. The general effect of rarefaction is to lessen the discontinuity in the phenomena, while raising the temperature, of ignition; and this is readily explained as due to the smaller frequency of the molecular encounters at a low pressure. On the other hand, the extinguishing power of SO_2 was found to be much diminished by rarefaction, the mixture $CS_2 + 5O_2 + 5SO_2$ igniting at 195° under a pressure of 150 mm.; and this has an influence on the ignition of mixtures which contained no SO_2 originally, since that gas is formed during the slow combustion in the period of delay which precedes ignition. Thus the mixture $CS_2 + 10O_2$ under a pressure of 750 mm. ignites at 160° after a delay of 1–2 seconds, and under a pressure of 300 mm. at 155° after a delay of as much as 15 seconds. These two effects of rarefaction act in opposite directions, and in some mixtures the one and in other mixtures the other of them has the preponderance.

8. *The Orthophote.* By JAMES T. BROWN.

An instrument for the instant and simultaneous correction of photometric observations for consumption of standard, volume of gas, and variations in the amount of gas consumed in the test burner.

This instrument, as arranged for use, with photometers fitted with graduated bars, consists of two similar, appropriately-calculated, logarithmic scales, with numbers and marks corresponding with those on the photometer bar. The lower scale is at the upper edge of the lower bar, and the upper scale is at the lower edge of the upper bar. These two scales are separated by an interval, in which a slide works freely. The lower half of the face of this slide is graduated in terms of the unit adopted as standard, and the upper half is occupied by a scale for the correction, of the gas consumed, for variations in atmospheric conditions. The normal, or standard lines of these two scales exactly correspond, and as they are engraved on the same sliding block they cannot be misplaced with reference to one another. Then, by moving the slide so that the number indicating the extent to which the standard has varied from its normal rate of consumption is opposite the bar-reading, the position of the normal line on that scale shows what the bar-reading would have been if the standard had consumed its correct quantity. Now, if the atmospheric conditions have been normal, that will be the corrected value of the gas; but if these are abnormal, the finally-corrected reading of the gas-value will be opposite the tabular (or Aërorthometer) number. If the standard employed does not require correction, the lower half of the slide has no scale. If the reading is taken by the quantity of gas required to render a disc evenly illuminated, that gas scale may be either on the lower, long bar, or on the lower half of the slide. The instrument can be fitted with the appropriate scales and slide for any photometer, any standard, and any range or quality of gas. It may be arranged vertically, or with the long scales on a bar sliding in a groove between the two short scales.

SATURDAY, SEPTEMBER 6.

The Section did not meet.

MONDAY, SEPTEMBER 8.

The following Reports and Papers were read:—

1. *Report of the Committee on an International Standard for the Analysis of Iron and Steel.*—See Reports, p. 262.

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2. *Report of the Committee on the Influence of Silicon on the Properties of Steel.*—See Reports, p. 262.

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3. *Report of the Committee on the Properties of Solutions.* See Reports, p. 310.

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4. *Report of the Committee on the Bibliography of Solution.* See Reports, p. 310.

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5. *On Recent Swedish Investigations on the Gases held in Solution by the Sea-water of the Skagerack.* *By* Dr. O. Pettersson.

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6. *Joint Discussion with Section A on the Nature of Solution and its Connection with Osmotic Pressure, opened by* S. W. Pickering, *F.R.S., in a Paper on the present Position of the Hydrate Theory of Solution.*—See Reports, p. 311.

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7. *The Molecular Refraction of Substances in Solution.* *By* J. H. Gladstone, *Ph.D., F.R.S.*—See Reports, p. 322.

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8. *On an Apparatus for the Determination of Freezing-points of Solutions.* *By* P. J. Hartog, *B.Sc., and* J. A. Harker.

In order to avoid the inconvenience and wastefulness involved in the use of ice and salt freezing mixtures, Raoult proposed to cool solutions by evaporation of a volatile liquid, such as carbon bisulphide. The authors have devised a convenient form of apparatus for this purpose, which has been rendered suitable not only for the exact determination of the freezing-point, but also for use in those cases so frequent in organic chemistry, where it is desirable that a reaction should take place without any considerable rise in temperature. It may also be used for crystallising salts, whose solubility diminishes with fall of temperature.

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9. *The Sulphur Waters of Yorkshire.* *By* C. H. Bothamley, *F.I.C., F.C.S.*

The sulphur waters of Yorkshire are divided geologically into two groups. One set of springs comes to the surface along a great anticlinal in the Yoredale beds which runs from Clitheroe, in Lancashire, to a little distance beyond Harrogate, the point at which the springs make their appearance in greatest number and volume. The springs of the other group rise in a deposit of river warp and gravel, with an overlying layer of peat, running along the base of magnesian limestones from beyond Pontefract to Doncaster; they are found in greatest number at Askern.

The Harrogate waters contain a large proportion of solid matter, sometimes rising to as much as 14 in 1,000. The greater part is sodium chloride, with magnesium and calcium chlorides also in considerable quantity; sulphates are absent; lithium, bromine, and iodine are present in small quantities. Perhaps the most remarkable fact is the presence of barium chloride in quantity amounting, in some cases, to nearly 10 grains in the gallon, or nearly double the amount of the total solid matter in the potable water supplied to Leeds. In the strong sulphur waters the proportion of hydrogen sulphide amounts to about 80 c.c. per litre. The waters are almost entirely free from organic matter, rise from comparatively deep-seated springs, and have retained their general character for a long period.

The Askern waters rise from no great depth, and may almost be regarded as surface waters. They contain a considerable quantity of dissolved peaty matter; and the proportion of hydrogen sulphide, which is all in the form of dissolved gas, reaches 50 c.c. per litre in the stronger springs. The total amount of solid matter is much lower than in the Harrogate waters, being about 2 parts in 1,000, and is totally different in its character. Chlorides are almost entirely absent, and the chief constituents are calcium carbonate and calcium and magnesium sulphates. Iodine is present in minute quantity; but potassium, lithium, bromine, and barium could not be detected in 5 litres of the water. This group of waters is still under investigation.

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10. *The River Aire: a Study in River Pollution.*[1] *By* T. H. Easterfield, *B.A., F.C.S., and* J. Mitchell Wilson, *M.D.*

The paper contained the result of a series of analyses of the water of the River Aire, from its source at Malham Cove to its junction with the Ouse above Goole. From these results it was shown:—(1) That the river, though a pure stream in its upper reaches, becomes more and more polluted as it passes through the townships of Gargrave, Skipton, Keighley, Shipley (with Bradford), Kirkstall, and Leeds; (2) That the curves exhibiting the ratio of pollution to mileage from the river source showed a series of maxima corresponding to the above centres of population, there being a tendency for the river to purify itself, to some slight extent, by natural causes when passing through areas in which no sensible amount of pollution was taking place; (3) That the Rivers Pollution Acts had been very inefficiently enforced in the basin of the River Aire.

TUESDAY, SEPTEMBER 9.

The following Reports and Papers were read:—

1. *Provisional Report of the Committee on the Bibliography of Spectroscopy.* See Reports, p. 261.

2 *Report of the Committee for preparing a new series of Wave-length Tables of the Spectra of the Elements.*—See Reports, p. 224.

3. *Report of the Committee on the Absorption-Spectra of Pure Compounds.* See Reports, p. 339.

4. *On Phosphorous Oxide. By* Professor T. E. Thorpe, *F.R.S.*

5. *Diazoamido-Compounds: a Study in Chemical Isomerism.*[2] *By* Professor Raphael Meldola, *F.R.S.*

The author gave a *résumé* of a series of experimental investigations with which he had been occupied, in conjunction with Mr. F. W. Streatfeild, for four years, and from which it appeared that when the hydrogen atom of mixed diazoamido-compounds is replaced by an alkyl radicle, three isomerides are capable of existence; whereas the prevailing view of the constitution of these compounds admits only of two isomerides. It has been found that the third isomeride can be produced in all cases by the combination of two unsymmetrical alkyl-diazoamides. Arguing from the view that the power of combination between the two isomerides is due to the unsaturated chain of nitrogen atoms, the author pointed out that combination might be expected to occur between two totally distinct unsymmetrical compounds. Experiment has justified this conclusion, and two cases were described in detail. From these results it follows that the molecular weight of the mixed diazoamides is double that of the generally-received formula. These compounds have been shown by previous investigators, as well as by the author, to behave under the influence of most reagents as though they contained two isomerides. The present researches tend to prove that this is actually the case, the two isomerides constituting the molecule of a mixed diazoamide being held together by the residue of affinity pertaining to the chains of

[1] Published *in extenso* in *Chem. News*, vol. lxii. p. 167, &c.
[2] See *Journ. Chem. Soc. Trans.* 1890, vol. lvii. p. 785.

nitrogen atoms. This view explains also the well-known fact that a mixed diazo-amide is the same in whichever order the amines are diazotised and combined. The third isomeride is, in fact, a polymeride; but in spite of this inevitable conclusion the depression of freezing-point in benzene solution, as determined by Raoult's method, agrees more closely with the half-molecular formula, a fact which indicates that dissociation takes place in solution. The force which binds together the constituents of the molecule is regarded by the author as similar in nature to that which holds together the constituents in a 'molecular compound.'

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6. *The Action of Light upon the Diazo-Compounds of Primuline and Dehydrothiotoluidine: a Method of Photographic Dyeing and Printing.* By ARTHUR G. GREEN, CHARLES F. CROSS, *and* EDWARD J. BEVAN.

In the early part of 1887 one of us (Green) discovered that by heating para-toluidine (2 mols.) with sulphur (4 to 5 atoms) at 200°–300° C. a very complex amido base was obtained, which on treatment with fuming sulphuric acid at a low temperature was converted into a sulphonic acid, the alkaline salts of which were easily soluble in water, and had the peculiar property of dyeing cotton primrose yellow from an alkaline or neutral bath without the use of a mordant. Further, the amido compound thus fixed upon the fibre could be diazotised *in situ* by passing the material through a weak solution of nitrous acid, and when diazotised could be combined with various phenols and amines, thus producing a variety of different colours, which, being formed within the fibre, were all distinguished by great fastness to washing, &c. The soluble amido sulphonic acid was named 'Primuline' by its discoverer, and has found a very extensive employment in cotton dyeing; the colours produced from it within the fibre were called 'Ingrain Colours.'[1]

Although the chemical constitution of primuline base (of which primuline is the mono-sulphonic acid) has not yet been determined with certainty, there is no doubt that it is a condensed derivative of dehydrothiotoluidine, a body which always accompanies it in its formation, and that it differs from the latter in exactly the same way as dehydrothiotoluidine itself differs from para-toluidine. As there is scarcely any doubt that dehydrothiotoluidine has the formula—

$$C_6H_3(CH_3)\langle{}^{S}_{N}\rangle C.C_6H_4(NH_2)$$

i.e., is an amido-benzenyl-amido-thiocresol, it follows that the formula of primuline, or rather of its chief constituent, is[2] probably

$$C_6H_3(CH_3)\langle{}^{S}_{N}\rangle C.C_6H_3\langle{}^{S}_{N}\rangle C.C_6H_3\langle{}^{S}_{N}\rangle C.C_6H_3(SO_3Na)(NH_2)$$

In a similar manner by heating meta-xylidine or pseudo-cumidine with sulphur, homologues of primuline are obtained, which, like primuline itself, dye cotton without a mordant, and can be diazotised and combined with phenols within the fibre.

It has been long observed by one of us (Green) that the diazo-compound of primuline was very sensitive to the action of light, being readily decomposed thereby, and losing its property of combining with phenols and amines. Upon this fact we have now founded a photographic process, by means of which designs can be produced in fast colours upon cotton, silk, wool, linen, or other fabrics. It can also be applied to wool, xylonite, celluloid, paper, or to gelatine films upon glass, thus affording a very wide range of employment. The process, which is a very simple one, merely depends upon the fact that if a material containing diazotised primuline be exposed to light under a design, those parts which are acted upon by light will be decomposed, whilst the parts protected from the light will

[1] A. G. Green, *Journ. Soc. Chem. Ind.* 1888, p. 179.

[2] A. G. Green, *Journ. Chem. Soc.* 1889, p. 227; *Ber.* 22, 968; P. Jacobsen, *Ber.* 22, 330; L. Gattermann, *Ber.* 22, 422; W. Pfitzinger and L. Gattermann, *Ber.* 22, 1063.

remain unaltered, and consequently, on subsequent development with a phenol or amine, will produce colours, whilst the decomposed portions will not. The details will of course depend somewhat upon the material to be treated. As an instance we may take the production of a design upon cotton cloth, cotton velveteen, &c. The material is first dyed with primuline from a hot bath containing common salt until the required depth is obtained. It is then washed and diazotised by being immersed for ¼ minute in a cold bath containing about ¼ p.c. of sodium nitrite, and strongly acidified with sulphuric or hydrochloric acid. The material is washed again, and exposed damp (or if preferred after having been dried in the dark) to the action of light beneath leaves, ferns, flowers, or other natural objects, or beneath glass or transparent paper upon which may be painted or printed any design which it is required to copy. Either the arc electric light or daylight may be employed; in the latter case the time of exposure will of course vary with the intensity of the light; under ½ minute is required in bright sunshine and nearly ½ hour in very dark cloudy weather. When the decomposition is complete, which may be readily ascertained by means of a test slip exposed simultaneously, the material is removed from the light and either passed into the developing bath at once, or is kept in the dark until it is convenient to develop it. The developing bath consists of a weak solution (¼ to ½ p.c.) of a phenol or amine made suitably alkaline or acid, the phenol or amine employed depending upon the colour in which it is required to produce the design, thus:—

For *red* . .	an alkaline solution of β-naphthol.
„ *maroon* .	an alkaline solution of β-naphthol-di-sulphonic acid.
„ *yellow* .	an alkaline solution of phenol.
„ *orange* .	an alkaline solution of resorcin.
„ *brown* .	a solution of phenylene diamine hydrochloride.
„ *purple* .	a solution of α-naphthylamine hydrochloride.

If it is required to produce the design in two or more colours, the respective developers, suitably thickened with starch, may be applied locally by means of a brush or pad. After development the material is thoroughly washed and requires no further fixing.

Linen, silk, and wool are treated in exactly the same way. Paper for copying drawings, &c., is coated on the surface with primuline by means of a brush or roller. For the production of gelatine films upon glass the primuline is incorporated with the gelatine before being applied to the glass.

In place of ordinary primuline the homologues already mentioned may be used. For silk and wool the primuline may be replaced by dehydrothiotoluidine-sulphonic acid, by means of which colourless backgrounds may be obtained.

Concerning the reaction which occurs when the diazo-primuline or the diazo-dehydrothiotoluidine is decomposed by light, we cannot at present say anything definite, except that the diazo group is completely destroyed, for on treatment with sodium hydrosulphite (true hyposulphite) it cannot be converted into the amido-group (re-forming primuline or dehydrothiotoluidine). The reaction may consist in a replacement of the N_2 group by OH or by H, or may be even more complex. Although we cannot affirm that this reaction to light is a property of the diazo-compounds of this group of bodies only, yet it is certain that they possess an extreme susceptibility to light far greater than that of other diazo-compounds, whilst at the same time they are far more stable to heat. It is thus possible that this property may depend in some way upon the sulphur which they contain.

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7. *Fast and Fugitive Dyes.*[1] *By* Professor J. J. Hummel.

The influence of light on dyed colours was considered, and after explaining that, according to Chevreul, the fading of such colours is due to the combined action of light, atmospheric oxygen, and moisture, the results of experiments made in the Dyeing Department of the Yorkshire College, Leeds, were briefly given. The

[1] *In extenso* vide *Textile Manufacturer*, 1890, vol. xvi. p. 506.

influence of mordants was observed to vary with different colouring-principles. Some, for example, those of alizarin, anthrapurin, flavopurpurin, nitro-alizarin, cœruleïn, alizarin blue, carminic acid, and others, give fast colours with all the usual mordants (Cr, Al, Sn, Cu, Fe); others, *e.g.* hæmateïn, give comparatively fast colours with Cr, Cu, Fe, and fugitive colours with Al and Sn; and others, again, *e.g.* fisetin, give fugitive colours with all mordants. With respect to colouring-matters not requiring the aid of mordants, they are found to comprise both fugitive and fast dyes, their behaviour differing, apparently, according to their chemical constitution. A comparison made between the natural and artificial colouring-matters showed that we have at the present time a total of about three times as many fast coal-tar colours as we have of fast natural dye-stuffs. Of the three hundred or so of distinct coal-tar colouring-matters, thirty give extremely fast colours, and an equal number or more give medium fast colours; whereas of the thirty natural dye-stuffs usually employed, only about ten may be reckoned as giving fast colours.

The general conclusion arrived at was that, if it were necessary or desirable, the modern textile colourist could, even now, dispense entirely with the natural dye-stuffs, and that, too, without any detriment to the permanency of his productions. Great stress was laid upon the necessity of employing the coal-tar colours aright, with discretion and intelligence, suiting the colouring-matter to the fabric and its ulterior use, whereby the evil repute into which they have fallen in many places would be entirely removed.

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8. *Notes on the Limits of the Reactions for the Detection of Hydrogen Dioxide, and the Reactions for Uranium.* *By* T. Fairley, *F.R.S.E.*

The results as regards very dilute solutions show:—

1. That on the addition of a dilute solution of uranium nitrate to one of hydrogen dioxide, it is preferable not to have an excess of hydrogen dioxide.

2. That a distinct precipitate is obtained on allowing a solution of 0·002 per cent. hydrogen dioxide to stand for two hours with excess of uranium nitrate.

3. That it is doubtful if less than 0·005 per cent. of hydrogen dioxide can be detected by the chromic acid and ether test.

4. That the limit of uranium which potassium ferrocyanide can detect is about 0·005 per cent. (very faint).

5. That the limit of uranium which hydrogen dioxide can detect is about 0·015 per cent.

Further, as regards the actual quantities detected, working with 5 c.c. of the solution in each case:—

2. 0·0001 grammes of hydrogen peroxide gave a precipitate with excess of uranium in two hours.

3. It is doubtful if less than 0·00025 grammes of hydrogen dioxide can be detected by the chromic acid and ether test in such dilute solutions as the above.

4. The limiting quantity of uranium which potassium ferrocyanide detected was 0·00025 grammes.

5. The limiting quantity of uranium which hydrogen dioxide detected was 0·00025 grammes.

WEDNESDAY, SEPTEMBER 10.

The following Papers were read:—

1. *On Veratrin, and on the Existence of Two Isomeric β-Picolines.* *By* Dr. F. Ahrens.

The experiments of Wright and of Bosetti on the action of alkalies were repeated and extended. It was found that when veratrin is treated with potash or with baryta water, or when it is heated to 200° C. with ammonia or distilled water, it is decomposed into angelic acid and a basic substance of the composition $C_{27}H_{43}NO_8$.

Important results were got by the dry distillation of veratrin, which yielded tiglic acid and β-picoline, and by the distillation of veratrin with lime, which yielded particularly isobutylene, β-picoline, and β-pipecoline. The picoline so formed has this peculiar property, that it is not miscible with water in all proportions, and is more soluble in cold than in hot water—a cold, saturated, aqueous solution becomes milky when very gently warmed. The picoline prepared from strychnine by Stoehr has the same properties, whereas the picoline prepared synthetically by Zanoni dissolves in water in all proportions. The boiling-points of the two picolines also differ by 6° C. Ladenburg found that the double salts formed by these two picolines with platinic chloride when boiled with water, both yield yellow crystalline sediments; these are identical in composition, but differ by 16° C. in their melting-points. Ladenburg concludes that two isomeric β-picolines must exist, and draws attention to the important theoretical consequences of this discovery.

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2. *The Action of Phosphorus Trichloride on Organic Acids and on Water.* *By* C. H. Bothamley *and* G. R. Thompson.

The action of phosphorus trichloride on organic acids is given in all text-books as a general method for the preparation of acid chlorides, and, with scarcely any exceptions, the reaction is represented by the equation, $3RCOOH + PCl_3 = 3RCOCl + H_3PO_3$. Some years ago, in his paper on 'Specific Volumes of Liquids,' Thorpe showed that in the case of acetic acid the reaction is properly represented by the equation, $3CH_3COOH + 2PCl_3 = 3CH_3COCl + 3HCl + P_2O_3$; but this fact has been overlooked, and the incorrect equation may be found in the most recent text-books.

The authors find that in the case of propionic and butyric acids the change is represented by a precisely similar equation, but that the reaction is liable to become complicated in presence of excess of one or other of the compounds. As a rule, a small quantity of the phosphorous oxide decomposes, with formation of P_4O and other products.

In the case of benzoic acid the reaction is much more complicated, the yield of benzoyl chloride being always lower than the calculated amount. Hydrochloric acid is evolved in large quantities in this case also.

It would seem that, although the chief reaction is expressed by the equation, $3RCOOH + 2PCl_3 = 3RCOCl + P_2O_3 + 3HCl$, and though, under certain conditions, this equation may be strictly true, especially with the acids of the acetic series of low molecular weight, many other changes may take place, to an extent depending on the conditions. Some of these changes are, interaction of the acid chloride with the unaltered acid; decomposition of the phosphorous oxide, which takes place more readily in presence of organic compounds, &c. Possibly, with acids of higher molecular weight some phosphorous acid may be formed, and this will interact with the phosphorus trichloride still present, forming phosphorous oxide and hydrochloric acid. This reaction, together with the subsequent decomposition of the P_4O_6, would explain the greater formation of P_4O in the case of acids of higher molecular weight. Direct evidence was obtained of the formation of benzoic acid by the interaction of phosphorous acid and benzoyl chloride.

The action of phosphorus trichloride on water takes place in accordance with the ordinary equation, $PCl_3 + 3H_2O = H_3PO_3 + 3HCl$, so long as the water is in considerable excess; but if the chloride is in excess it reacts with the phosphorous acid, with formation of hydrochloric acid and yellow phosphorous oxide mixed with other oxides, and, in some cases, with free phosphorus. In the interaction of water and excess of phosphorus trichloride, the authors obtained the soluble form of P_4O or P_4OH in the cooler parts of the vessel; but if exposed to a temperature above 70° it became insoluble, a result which agrees with an early statement of Gautier.

In the interaction of phosphorus trichloride and organic acids we may, therefore, have several reactions taking place simultaneously, and the extent to which any one of them proceeds will depend largely on the temperature. The action of phosphorus trichloride cannot be regarded as a good general method for the preparation of acid chlorides; it gives good results only in the case of the lowest members of the acetic series.

3. *On the Constitution of the Alkaloid, Berberin.* *By* Professor W. H. Perkin, Jun., *F.R.S.*

4. *The Production of Camphor from Turpentine.* *By* J. E. Marsh *and* R. Stockdale.

5. *On a Double Aspirator.* *By* T. Fairley, *F.R.S.E.*

6. *On the Vulcanisation and Decay of Indiarubber.* *By* W. Thomson, *F.R.S.E., F.C.S.*

Indiarubber is vulcanised to alter its character, so that it will not become hard when exposed to cold, or soft and plastic when exposed to heat. Vulcanisation is usually effected by incorporating sulphur with the rubber, and then heating the mixture to a high temperature, when the sulphur combines with the rubber, producing vulcanised rubber.

In making waterproof cloth for 'macintoshes,' the rubber cannot be heated to a high temperature, as that would be liable to make the cloth tender, or to damage the dye on it. In this case the so-called 'cold vulcanising process' is employed, which consists in the application of a mixture of chloride of sulphur dissolved in bisulphide of carbon; the latter penetrates the layer of rubber, carrying with it the chloride of sulphur: and it is generally believed that the sulphur of the chloride of sulphur combines with the rubber, producing vulcanisation, whilst the chlorine combines with the hydrogen of the rubber, producing hydrochloric acid. The author showed by analysis that the chlorine, more than the sulphur, produced the vulcanisation, and found about $6\frac{1}{2}$ per cent. of chlorine in combination with the rubber for every $2\frac{1}{2}$ per cent. of sulphur present, part of which was in the free or uncombined condition. The higher chlorides of sulphur are liable to produce over-vulcanisation, and this is generally explained on the assumption that these compounds break up more easily than the lower chlorides, thus giving to the rubber an excess of sulphur. The author points out that this is simply due to the excess of chlorine which combines with the rubber.

Vegetable oils are converted into a solid substance resembling rubber by treatment with a mixture of the chloride of sulphur and bisulphide of carbon, and the author finds that here, also, the vulcanisation of the oil is due to the chlorine more than to the sulphur present. Vulcanised oil, called rubber-substitute, contains a liquid, oily matter, which is generally supposed to be injurious to indiarubber; and as this substitute is employed for mixing with rubber, manufacturers often reject 'rubber-substitute' which contains much of this substance. He found that this oily matter, instead of acting injuriously on rubber, like the oil from which it is produced, tends to preserve it, by preventing oxidation.

It is known that copper salts have a most injurious effect on indiarubber, and as copper is sometimes used in dyeing blacks and other colours, cloths so dyed are liable to decompose and harden the rubber put upon them. A peculiarity investigated by the author is that metallic copper placed in contact with thin sheets of indiarubber brings about oxidation and hardening of its substance, although no appreciable quantity of copper enters the indiarubber. Metallic platinum also produces, but to a much less extent, the same effect; whilst metallic zinc and silver have an injurious effect on the rubber.

7. *On the Unburned Gases contained in the Flue-gases from Gas Stoves and different Burners.* *By* WILLIAM THOMSON, *F.R.S.E., F.C.S.*

The author has been working for some time with a view of determining whether the gases escaping as flue-gases from gas-stoves and different burners were really free from gas capable of combustion, such as carbon monoxide, or unburned hydrocarbons or hydrogen. He spent some time in trying to separate and determine the quantity of carbon monoxide present, if any; but this problem was beset with so many difficulties, that for the moment he abandoned it, and contented himself for the present with determining the quantity of unburned carbon and hydrogen, in whatever forms these might exist. For this purpose he arranged an apparatus consisting of two carefully-weighed U-tubes filled with strong sulphuric acid, and two U-tubes filled with soda-lime, through which the flue-gases were first passed; these absorbed the water and carbon dioxide contained in the flue-gases, leaving the hydrocarbons (not absorbed by oil of vitriol), hydrogen, and carbon monoxide to pass through a redhot glass tube filled closely, to the extent of 15 inches, with oxide of copper prepared *in situ* from copper-wire gauze. The gases were then passed through strong sulphuric acid and soda-lime contained in previously-weighed U-tubes, and the results were calculated on the gas measured at 60° Fahrenheit and 30 inches barometric pressure, from the measure of gas drawn into the aspirator (treated as water-saturated gas), and the carbon dioxide and water-vapour absorbed in the tubes were then added on, to make up the measure of flue-gas originally employed.

The coal-gas employed was previously passed through large cylinders filled with calcium chloride, to dry it before combustion; and at the time when the experiment was going on, and side by side with it, were estimated the carbon dioxide and water-vapour present in the air itself, by passing them, by means of another aspirator, through strong sulphuric acid and soda-lime in U-tubes previously weighed.

The carbon dioxide in the air itself ranged from 0·41 to 0·66 grains per cubic foot of air, and the water from 3·51 to 7·23 grains in the same volume.

The amounts of carbon dioxide and water collected from the flue-gases, after deducting the quantities actually present in the air, were taken as those due to the combustion of the coal-gas.

The standard employed was the one used by Professor Roberts-Austin in his analysis of the flue-gases from the burning of coal, and the apparatus employed was also generally similar to that employed by him.

The carbon and hydrogen left unburned were measured in terms of 1,000 parts of carbon completely burned, derived from the combustion of the gas in the stove or burner.

The total quantities of carbon dioxide and of water in the flue-gases amounted to from 6·6 to 10·8 grains per cubic foot for the former, and from 5·6 to 10·5 grains of the latter, in the same volume.

The amount of flue-gas passed in each experiment was about 1 cubic foot, and although the variations were considerable, the general results were conclusive in showing that the combustion of gas when burned in gas stoves for heating purposes is much more incomplete than one might be led to believe.

The only burner in which the weights of the tubes remained constant after passing the burned gas, and in which the combustion was complete, was in a paraffin oil lamp in which the flame was not turned to the highest point. Another experiment with the flame turned on gave 12·04 and 3·09 respectively of carbon and hydrogen unburned per 1,000 of carbon completely burned.

The next nearest approach to complete combustion was in an Argand burner, in which the carbon compounds were completely burned; but an amount representing 0·2575 parts of hydrogen per 1,000 parts of carbon completely burned was registered in one experiment, whilst in a second experiment 0·113 of carbon, 2·5414 of hydrogen were registered per 1,000 parts of carbon completely burned. Then came a flat flame, Bray's burner, burning 4 cubic feet per hour, which gave 11·12 of carbon and 0·95 hydrogen unburned per 1,000 of carbon completely burned.

Following in order these results came the Welsbach light, in which the gas heats to whiteness a tube or mantle, composed of a filmy thickness, of the oxides of Zirconium and Thorium, the mantle being surrounded by a glass tube similar to that used in some paraffin oil lamps; in this case the unburned carbon exceeded in amount the unburned hydrogen, there being 15·486 of the former and 3·794 of the latter per 1,000 of completely burned carbon.

Three experiments were made with a Marsh-Greenall's heating stove, in which three Bray's luminous burners were employed.

The first was made with a consumption of 5·62 cubic feet of gas per hour, when 12·6 and 3·0 parts of carbon and hydrogen respectively were registered per 1,000 parts of carbon completely burned.

The second experiment, with a consumption of 5·74 cubic feet per hour, gave 37·6 and 11·8 respectively of carbon and hydrogen unburned.

The third experiment, with an increased consumption of gas (7·1 cubic feet per hour), gave 97·4 and 12·1 of carbon and hydrogen respectively unburned.

Two experiments were made with one of T. Fletcher's heating stoves, in which eight Bunsen burners play upon some fancy metal-work (iron coated with magnetic oxide); the one experiment, in which the amount of gas passing was not measured, gave 43·3 of carbon and 24·6 of hydrogen unburned per 1,000 of carbon completely burned.

In the second experiment, where 6·81 cubic feet of gas were burned per hour, 66·3 and 20·0 respectively of carbon and hydrogen unburned were registered.

One experiment was made with one of T. Fletcher's stoves in which twenty Bunsen burners play on asbestos projecting from a fire-clay back; with a consumption of 8·14 cubic feet of gas, 138·9 and 11·7 parts respectively of carbon and hydrogen per 1,000 parts of completely burned carbon were formed.

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8. *Contributions to the Analysis of Fats.*[1]
By J. Lewkowitsch, *Ph.D., F.I.C., F.C.S.*

The author gave in brief outline a review of the methods for the chemical analysis of fats. He recommended for the estimation of glycerol in fats, as the most exact method, the combination of the alcohol-ether extraction with Benedikt and Cantor's acetic method, which he has shown to give concordant results. The various methods for determining the nature of the various fats, and especially of the fatty acids, were shown by means of an analytical table, and the methods of Hehner, Reichert, Köttstorfer, Hübl, and Hazura were referred to.

The author took objection to Benedikt's method of determining the 'acetyl value'—*i.e.*, to give a value for hydroxylated acids present in a fat. Benedikt assumed that hydroxylated fatty acids, on being boiled with acetic anhydride, were acetylated, and transformed into acetyl hydroxylatids. On titrating these products in alcoholic solution with standard alkali, Benedikt obtained a certain acid value, due to the COOH group (as he thought) of the (supposed) acid, and, on saponification, when the acetyl was split off, a larger saponification value; the difference between the two values yielded the 'acetyl value.' The two reactions that were to take place may be expressed by the following equations for ricinolic acid:—

1. $C_{17}H_{32}(OC_2H_3O)COOH + 1KOH = C_{17}H_{32}(OC_2H_3O)COOK + H_2O.$
2. $C_{17}H_{32}(OC_2H_3O)COOH + 2KOH = C_2H_3O, OK + C_{17}H_{32}(OH)COOK + 2H_2O.$

The author, however, has shown that on boiling fatty acids with acetic anhydride the acids are transformed into their *anhydrides*, and he has proved this for capric, lauric, palmitic, stearic, cerotic, and oleic acids. A hydroxylated acid, *e.g.*, dihydroxystearic acid, which was prepared from oleic acid, undergoing this operation will, of course, become acetylated, but at the same time anhydrated, so that the resulting product is nothing else than diacetylhydroxystearic anhydride. These anhydrides give no acid value, and all the 'acid values' which Benedikt has found in his experiments are only due to the fact that he dissolved the products of the

[1] *Journ. of the Society of Chemical Industry*, 1890, p. 842.

action of acetic anhydride on the acids in alcohol, when a partial hydrolysis of the anhydrides took place. Had he shaken up his substances with water he would, on titrating, have found no acid value, or a very small value, owing to slight hydrolysis in aqueous solution. The experiments of the author on dihydroxystearic anhydride prove his conclusions beyond doubt.

The method of boiling fatty acids with acetic anhydride may qualitatively indicate the presence of hydroxylated fatty acids, and this will be the case if the saponification values of the original fatty acid and of the acetylated fatty acid shows a considerable difference. The real 'acetyl values' will be found by quantitatively estimating the amount of acetyl (as acetic acid) that has been taken up by the fatty acid on boiling with acetic anhydride.

The author has shown that this may be conveniently done by means of a method closely resembling that of Reichert. He estimated the 'acetyl' in the diacetylhydroxystearic acid in this way, and found results concordant with those required by theory.

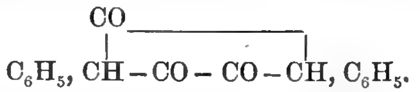
9. *On the Condensation of Dibenzylketone with Oxalic Ether.* *By* THOS. EWAN, *Ph.D., B.Sc.*

The author, who undertook this work at the suggestion of Professor Claisen, found that dibenzylketone and oxalic ether condense together, under the influence of sodium ethylate, according to the equation—

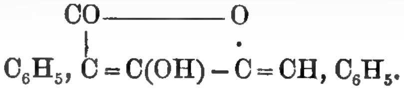
$$C_{15}H_{14}O + C_6H_{10}O_4 = C_{17}H_{12}O_3 + 2C_2H_5OH.$$

The substance so obtained (oxalyldibenzylketone) forms yellow plates melting at 189–190°. On boiling with caustic potash it is decomposed, with formation of dibenzylketone. It forms salts, in which either one or two atoms of hydrogen are replaced by metal. These two hydrogen atoms can also be replaced by methyl groups. The monomethyl compound, on boiling with caustic potash, yields a methyldibenzylketone, while the dimethyl compound gives the monomethyl compound again. Acetic anhydride converts it into a monacetyl derivative. It also yields an anilide, hydrazone, and an oxime. With m.p. toluylene diamine it gives a phenazine.

From the method of formation, and the above reactions, there is no doubt that the substance possesses the constitution—



When heated above its melting-point it changes into an isomeric substance melting at 249°. Its salts contain only one atom of metal; it forms also an acetyl derivative. On boiling with potash it is decomposed, with formation of dibenzyl glycolic acid. It is therefore probably represented by the formula—



Section C.—GEOLOGY.

President of the Section—Professor A. H. Green, M.A., F.R.S., F.G.S.

THURSDAY, SEPTEMBER 4.

The President delivered the following Address:—

The truth must be told; and this obliges me to confess that my contributions to our stock of geological knowledge, never very numerous, have of late years been conspicuously few, and so I have nothing to bring before the Geological Section that can lay any claim to be the result of original research.

In fact, nearly all my time during the last fifteen years has been taken up in teaching. This had led me to think a good deal about the value of geology as an educational instrument, and how its study compares with that of other branches of learning in its capability of giving sinew and fibre to the mind, and I have to ask you to listen to an exposition of the notions that have for a long time been taking shape bit by bit in my mind on this subject.

I am not going to enter into the question, handled repeatedly and by this time pretty well thrashed out, of the relative value of natural science, literature, and mathematics as a means of educational discipline; for no one who is lucky enough to know a little of all three, will deny that each has an importance of its own and its own special place in a full and perfect curriculum. The question which is the most valuable of the three I decline to entertain, on the broad general ground that 'comparisons are odorous,' and for the special reason that the answer must depend on the constitution of the mind that is to be disciplined. I might quite as reasonably attempt to lay down that a certain diet which suits my constitution and mode of life, must agree equally well with all that hear me.

I need scarcely say that nothing would induce me, if it could possibly be helped, to say one word that might tend to disparage the pursuit to which we are all so deeply attached. But I cannot shut my eyes to the fact that, when geology is to be used as a means of education, there are certain attendant risks that need to be carefully and watchfully guarded against.

Geologists, and I do not pretend myself to be any better than the rest of them, are in danger continually of becoming loose reasoners. I have often had occasion to feel this, and I recall a scene which brought it home to me most forcibly. At a gathering, where several of our best English geologists were present, the question of the cause of changes of climate was under discussion. The explanation which found most favour was a change of the position of the axis of rotation within the earth itself; and this, it was suggested, might have been brought about by the upheaval of great bodies of continental and mountainous land where none now exist, and an accompanying depression of the existing continents or parts of them. That such a redistribution of the heavier material of the earth would result in some shifting of the axis of rotation admits of no doubt. The important question is, How much? What degree of rearrangement of land and sea would be needed to produce a shift of the amount required? It is purely a question of figures, and the necessary calculations can be made only by a mathematician. I ventured to suggest that some one who could work out the sum should be consulted before a final decision was arrived at, for I knew perfectly well that not one of the company present could do it. But if I say that my advice met with scant approval, I should represent very inadequately the lack of support I met with. The bulk of those present seemed quite content with the vague feeling that the thing could be done in the way suggested, and there was a general air of indifference as to whether the hypothesis would stand the test of numerical verification or not.

I could bring many other similar instances which seem to me to justify the charge I have ventured to make; but it will be more useful to inquire what it is that has led to a failing, which, if it really exist, must be a source of regret to the whole brotherhood of hammerers.

The reason, I think, is not far to seek. The imperfection of the Geological Record is a phrase as true as it is hackneyed. No more striking instance of its correctness can be found than that furnished by the well-known Mammalian jaws from the Stonesfield slate. The first of these was unearthed about 1764, others, to the number of some nine, between then and 1818. The rock in which these precious relics of the beginning of mammalian life occur has been quarried without intermission ever since ; it has been ransacked by geologists and collectors without number; many of the quarrymen know a jaw when they see it, and are keenly alive to the market value of a specimen; but not one of these prized and eagerly-sought-after fossils has turned up during the last seventy years.

Then again how many of the geological facts which we gather from observation admit of diverse explanation. Take the case of *Eozoon Canadense*. Here we have structures which some of the highest authorities on the Foraminifera assure us are the remains of an organism belonging to that order; other naturalists, equally entitled to a hearing, will have it that these structures are purely mineral aggregates simulating organic forms. And hereby hangs the question whether the limestones in which the problematical fossil occurs are organic, or formed in some other and perhaps scarcely explicable way.

And this after all is only one of the countless uncertainties that crowd the whole subject of invertebrate palæontology. In what a feeble light have we constantly to grope our way when we attempt the naming of fossil Conchifers for instance. The two species *Gryphæa dilatata* and *G. bilobata* furnish an illustration. Marked forms are clearly separable, but it is easy to obtain a suite of specimens, even from the Callovian of which the second species is said to be specially characteristic, showing a gradual passage from one form into the other. And over and over again the distinctions relied upon for the discrimination of species must be pronounced far-fetched and shadowy, and are, it is to be feared, often based upon points which are of slender value for classificatory purposes. In the case of fossil plants the last statement is notoriously true, and yet we are continually supplied with long lists of species which every botanist knows to be words and nothing more, and zonal divisions are based upon these bogus species and conclusions drawn from them.

It is from data such as have been instanced, scrappy to the last degree, or from facts capable of being interpreted in more than one way, or from determinations shrouded in mist and obscurity, that we geologists have in a large number of cases to draw our conclusions. Inferences based on such incomplete and shaky foundations must necessarily be very largely hypothetical. That this is the character of a great portion of the conclusions of geology we are all ready enough to allow with our tongue—nay, even to lay stress upon the fact with penned or spoken emphasis. But it is open to question whether this homage at the shrine of logic is in many cases anything better than lip-service; whether we take sufficiently to heart the meaning of our protestations, and are always as alive as our words would imply to the real nature of our inferences.

A novice in trade, scrupulously honest, even morbidly conscientious to begin with, if he lives among those who habitually use false scales, runs imminent risk of having his sense of integrity unconsciously blunted and his moral standard insensibly lowered. A similar danger besets the man whose life is occupied in deducing tentative results from imperfectly ascertained facts. The living, day by day, face to face with approximation and conjecture must tend to breed an indifference to accuracy and certainty, and to abate that caution and that wholesome suspicion which make the wary reasoner look well to his foundations, and resolutely refuse to sanction any superstructures, however pleasing to the eye, unless they are firmly and securely based.

If I am right in thinking that the mental health of the geologist of matured experience and full-grown powers is liable to a disorder of the kind I have indicated, how much greater must the risk be in the case of a youth, in whom the reasoning faculty is only beginning to be developed, when he approaches the study of geology! And does it not seem at first sight that that study could scarcely be used with safety as a tool to shape his mind, and so train his bent that he shall never even have a wish to turn aside either to the right hand or to the left from the strait path that leads through the domain of sound logic?

That it is hazardous, and that evil may result from an incautious use of geology as an educational tool, I entertain no doubt. The same may indeed be said of many other subjects, but I feel that it is specially true in the case of geology. But I should be guilty of that very haste in drawing conclusions against which I am raising a warning word, if I therefore inferred that geology can find no place in the educational curriculum.

To be forewarned is a proverbial safeguard, and those who are alive to a danger will cast about for a means of guarding against it. And there are many ways of neutralising whatever there may be potentially hurtful in the use of geology for educational ends. It has been said that the right way to make a geologist is not to teach him any geology at all to begin with. To send him first into a laboratory, give him a good long spell at observations and measurements requiring the minutest accuracy, and so saturate his mind with the conception of exactness that nothing shall ever afterwards drive it out. If a plan like this be adopted, it is easy to pick out such kinds of practical work as will not only breed the mental habits aimed at, but will also stand him in good stead when he goes on to his special subject. Goniometrical measurements and quantitative analysis will serve the double purpose of inspiring him with accurate habit of thought, and helping him to deal with some of the minor problems of geology. And I cannot hold that this practice of paying close attention to minute details will necessarily unfit a man for taking wider sweeps and more comprehensive views later on. That habit comes naturally to every man who has the making of a geologist in him directly he gets into the field. Put such a man where a broad and varied landscape lies before him, teach him how each physical feature is the counterpart of geological structure, and breadth of view springs up a native growth. I do not mean to say that the plan just suggested is the only way of guarding against the risk I have been dwelling upon. There are many others. This will serve as a sample to show what I think ought to be aimed at in designing the geological go-cart. And any such mind-moulding leads, be assured, not to hesitancy and doubt, but to conclusions, reached slowly it may be, but so securely based that they will seldom need reconstruction.

There is another aspect of the question. The uncertainties with which the road of the geologist are so thickly strewn have an immense educational value, if only we are on our guard against taking them for anything better than they really are. Of those stirring questions which are facing us day by day and hour by hour, none perhaps is of greater moment than the discussion of the value of the evidence on which we base the beliefs that rule our daily life. A man who is ever dealing with geological evidence and geological conclusions, and has learned to estimate these at their real value, will carry with him, when he comes to handle the complex problems of morals, politics, and religion, the wariness with which his geological experience has imbued him.

Now I trust the prospect is brightening. Means have been indicated of guarding against the danger which may attend the use of geology as an educational instrument. Need I say much to an audience of geologists about the immense advantages which our science may claim in this respect? In its power of cultivating keenness of eye it is unrivalled, for it demands both microscopic accuracy and comprehensive vision. Its calls upon the chastened imagination are no less urgent, for imagination alone is competent to devise a scheme which shall link together the mass of isolated observations which field work supplies; and if, as often happens, the fertile brain devises several possible schemes, it is only where the imaginative faculty has been kept in check by logic that the one scheme that best fits each case will be selected for final adoption. But, above all, geology has its home, not in the laboratory or study, but *sub Jove*, beneath the open sky; and its pursuit is inseparably bound up with a love of Nature, and the healthy tone which that love brings alike to body and mind.

And what does the great prophet of Nature tell us about this love?

> The boy beholds the light and whence it flows;
> The man perceives it die away,
> And fade into the light of common day.

Will it not then be kind to encourage the boy to follow a pursuit which will keep alive in him a joy which years are too apt to deaden; and will not the teaching of geology in schools conduce to this end? Geology certainly should be taught in schools, and for more prosaic reasons, of which the two following are perhaps the most important. Geography is essentially a school subject, and the basis of all geographical teaching is physical geography. This cannot be understood without constant reference to certain branches of geology. Again how many are the points of contact between the history of nations, the distribution and migrations of peoples, and the geological structures of the lands they have dwelt in or marched over.

But geology is not an easy subject to teach in schools. The geology of the ordinary text-book does not commend itself to the boy-mind. The most neatly-drawn sections, nay, even the most graphic representations of gigantic and uncouth extinct animals, come home to the boy but little, because they are pictures and not things. He wants something that he can handle and pull about; he does not refuse to use his head, but he likes to have also something that will employ his hands at the same time.

The kind of geology that boys would take to is outdoor work; and, of course, where it can be had, nothing better could be given them. A difficulty is that field work takes time and filches away a good deal of the intervals that are devoted to games. Still cross-country rambles and scrambling about quarries and cliffs are not so very different from a paper-chase; and if the teacher will only infuse into the work enough of the fun and heartiness which come so naturally in the open air, he need not despair of luring even the most high-spirited boy, every now and then, away from cricket and football.

But there are localities not a few—the Fen country, for instance—where it is scarcely possible to find within manageable distance of the school the kind of field-geology which is within the grasp of a beginner. But even here the teaching need not be wholly from books. The best that can be done in such cases is to make object-lessons indoors its basis. For instance, give a lad a lump of coarsish sandstone; let him pound it and separate by elutriation the sand grains from the clay; boil both in acid, and dissolve off the rusty coating that colours them; ascertain by the microscope that the sand grains are chips and not rounded pellets, and so on. All such points he will delight to worry out for himself; and, when he has done that, an explanation of the way in which the rock was formed will really come home to him. Or it is easy to rig up contrivances innumerable for illustrating the work of denudation. A heap of mixed sand and powdered clay does for the rock denuded; a watering-can supplies rain; a trough, deeper at one end than the other, stands for the basin that receives sediment. By such rough apparatus many of the results of denudation and deposition may be closely imitated, and the process is near enough to the making of mud-pies to command the admiration of every boy. It is by means like these that even indoor teaching of geology may be made lifelike.

I need not dwell upon the great facts of physical geology which have so important a bearing on geography and history; but I would, in passing, just note that these too often admit of experimental illustration, such for instance as the well-known methods of imitating the rock folding caused by earth-movements. I would add that wherever in speaking of school teaching, I have used the word 'boy,' that word must of course be taken to include 'girl' as well.

In conclusion I should like to give you an outline of the kind of course I endeavour to adopt in more advanced teaching in the case of students who are working at other subjects as well and can give only a part of their time to geology. During the first year the lectures and bookwork should deal with physical geology. In the laboratory the student should first make the acquaintance of the commoner rock-forming minerals, the means of recognising them by physical characters, blowpipe tests, and the simpler methods of qualitative analysis, and may then go on to work at the commoner kinds of rocks and the elements of microscopic petrography. During the summer months I would take him into the field, but not do more than impress upon him some of the broader aspects of outdoor work, such as the connection between physical feature and geological structure.

During a second year stratigraphical geology should be lectured upon and studied from books, and so much of animal morphology as may be necessary for palæontological purposes should be mastered. The practical work would lie mainly among fossils, with a turn every now and again at mineralogy and petrology to keep these subjects going. Out of doors I would not yet let the student attempt geological mapping, but would put into his hands a geological map and descriptions of the geology of his neighbourhood, and he would be called upon to examine in minute detail all accessible sections, collect and determine fossils, and generally see how far he can verify by his own work the observations of those who have gone before him.

Indoor work during the third year would be devoted to strengthening and widening the knowledge already gained. Out of doors the student should attempt the mapping of a district by himself. It will be well, if there is any choice in the matter, to select one in which the physical features are strongly marked.

This sketchy outline must serve to indicate the notions that have grown up in my mind on the subject now before us, and the methods I have been led to adopt in the teaching of geology. I trust that they may be suggestive, and may call forth that kindly and genial criticism with which the brotherhood of the hammer are wont to welcome attempts, however feeble, to strengthen the corner-stones and widen the domain of the science we love so well, and to enlarge the number of its votaries.

The following Papers were read :—

1. *On the Gigantic Ceratopsidæ (or Horned Dinosaurs) of North America.* *By* Professor O. C. Marsh.

In this paper the author gave the principal characters of the huge horned Dinosaurs which he had recently secured from the Laramie formation of North America. These reptiles differ widely from any other known Dinosaurs, and he has placed them in a distinct family, the *Ceratopsidæ*.[1]

The geological horizon in which they are found is in the Upper Cretaceous, and has now been traced nearly eight hundred miles along the eastern side of the Rocky Mountains. It is marked almost everywhere by remains of these reptiles, and hence the strata containing them have been called the Ceratops beds. They are freshwater or brackish deposits, which form a part of the so-called Laramie, but are below the uppermost beds referred to that group. In some places they rest upon marine beds which contain invertebrate fossils characteristic of the Fox Hills deposits.

The fossils associated with the *Ceratopsidæ* are mainly Dinosaurs, representing

[1] *American Journal of Science*, 3rd series, vol. xxxvi. p. 477, December 1888. See also vol. xxxvii. p. 334, April 1889; vol. xxxviii. p. 173, August 1889; p. 501, December 1889; and vol. xxxix. p. 81, January 1890; p. 418, May 1890.

two or three orders and several families. Plesiosaurs, crocodiles, and turtles of cretaceous types, and many smaller reptiles, have left their remains in the same strata. Numerous small mammals, also of ancient types, a few birds, and many fishes, are likewise entombed in this formation. Invertebrate fossils and plants are not uncommon in the same horizon.

The skull of *Triceratops*, the best known genus of the family, has many remarkable features. First of all its size, in the largest individuals, exceeds that of any land animal, living or extinct, hitherto discovered, and is only surpassed by that of some of the Cetaceans. The skull, represented natural size in one of the diagrams shown, was that of a comparatively young animal, but is about six feet in length. The type of *Triceratops horridus* was an old individual, and the head, when complete, must have been nearly eight feet in length. Two other skulls, both nearly perfect, were also represented by life-size sketches, and others from the same horizon have equal dimensions.

Another striking feature of this group is its armature. This consisted of a sharp cutting beak in front, a strong horn on the nose, a pair of very large pointed horns on the top of the head, and a row of sharp projections around the margin of the posterior crest. All these had a horny covering of great strength and power. For offence and defence they formed together an armour for the head as complete as any known. This armature dominated the skull and in a great measure determined its form and structure.

The skull itself is wedge-shaped in form, especially when seen from above. The facial portion is very narrow and much prolonged in front. In the frontal region the skull is massive and greatly strengthened to support the large and lofty horn-cores which formed the central feature of the armature. The huge expanded posterior crest which overshadowed the back of the skull and neck was evidently of secondary growth, a practical necessity for the attachment of the powerful ligaments and muscles that supported the head.

The brain of *Triceratops* appears to have been smaller in proportion to the entire skull than in any known vertebrate. Its position and relative size were shown in a diagram. The position of the brain in the skull does not correspond to the axis of the latter, the front being elevated at an angle of about thirty degrees.

The teeth of *Triceratops* and its near allies are very remarkable in having two distinct roots. This is true of both the upper and lower series. These roots are placed transversely in the jaw, and there is a separate cavity, more or less distinct, for each of them. One of these teeth was represented by an enlarged figure and another tooth was itself exhibited. The teeth form a single series only in each jaw, but the grinding surface is reversed, being on the inner side of the upper series and on the outer side of the lower series.

The atlas and axis of *Triceratops* are co-ossified with each other, and at least one other vertebra is firmly united with them. These form a solid mass well adapted to support the enormous head. The remaining cervical vertebræ are short and have the articular faces of the centra nearly flat.

The trunk vertebræ have very short centra with flat articular ends. The posterior trunk vertebræ have diapophyses with faces for both the head and tubercle of the ribs, as in crocodiles. The sacrum was strengthened by union with several adjacent vertebræ, ten in all being co-ossified in one specimen of *Triceratops*. The caudal vertebræ are short and rugose, and the tail was of moderate length.

The ilium is elongated and massive and the front portion more expanded than the posterior. The ischium is slender and curved inward and backward. The pubis extends forward and its distal end is much expanded. Its posterior branch is wanting.

The limbs were short and massive and all four were used in locomotion. The feet were all provided with broad hoofs. All the bones of the skeleton appear to have been solid. Dermal ossifications were present and some species were protected by armour.

The main characters which separate the *Ceratopsidæ* from all other known families of the *Dinosauria* are as follows:

1. A rostral bone forming a sharp cutting beak.

2. The skull surmounted by massive horn-cores.
3. The expanded parietal crest with its marginal armature.
4. The teeth with two distinct roots.
5. The anterior cervical vertebræ co-ossified with each other.
6. The posterior dorsal vertebræ supporting on the diapophysis both the head and tubercle of the rib.

The *Ceratopsidæ* resemble, in various points, the *Stegosauria* of the Jurassic, especially in the vertebræ, limbs, and feet. The greatest difference is seen in the skull, but the pelvic arch also shows a wide divergence. In the *Ceratopsidæ* there is no marked enlargement of the spinal cavity in the sacrum, and there is no postpubis.

In conclusion, the author stated that on this group of Dinosaurs he had in preparation an illustrated memoir, which would be published by the United States Geological Survey.

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2. *The Carboniferous Strata of Leeds and its immediate suburbs.* *By* BENJAMIN HOLGATE, *F.G.S.*

As is well known, Leeds stands in an enviable position as regards its minerals. Situated as it is on the lower coal measures, it is rich in coarse and fine building and monumental stone of the greatest durability, of stone suitable for some kinds of grindstones, and of iron ores of such quality that it has taken steel to even partially displace the iron made from it. Another industry has arisen, namely, that of brickmaking, which places us in a better position than perhaps any other town for making a minute investigation of a great section of measures as exposed in its open clay quarries. The bricks are made, not from any particular seam or bed, but from all the strata by mixing and grinding together the most siliceous, dry, and stony strata with those of a more bituminous, oily, and clayey kind, the result being a brick hard, durable, and strong, and thus almost every cubic foot of the strata is made use of.

Some of these quarries are 70 feet in depth, and, as they are being constantly worked at, they always present a fresh face, and it so happens that, owing to the dip of the strata and the position of the quarries, the tops of some are at about the same horizon as the bottoms of others. We thus have a succession of different varieties of strata representing a vertical section of upwards of 300 feet, and including four well-known and important coal seams, namely, the 'Better,' 'Black,' 'Crow,' and 'Beeston Beds,' the latter eight feet in thickness and fully exposed to view. Different fireclays, some of them of the greatest value and much worked, are also exposed. The sections show the ever varying conditions under which they were deposited.

At some horizons we have fine binds or shales of light colour entombing the fronds of ferns and most delicately marked plants.

At others, darker shales, which entomb stems, roots, and fruits; and again in others strong black oily shales, which contain the remains of many fishes and shells. Here we see indications of a quiet nook in which light plants have floated, become water-logged, and sunk. There we find the ripple-mark and the worm-burrow which inform us that the strata were deposited in a tidal estuary.

At one horizon we obtain a mineral water containing magnesia and sulphur in such quantities that it was at one time celebrated as a spa water, until sought after for manufacturing purposes, and spoilt by being mixed with those from other layers.

At another horizon we have water containing such an amount of chloride of sodium and magnesium that it is as salty as sea water.

The fossils are numerous individually, but meagre in the number of species; but some of the stigmaria, calamites, lepidostrobi, and dadoxylons are perhaps the most suitable for examination of any that have been discovered, as their structure has been preserved.

These strata show almost every variety of conditions of the coal period.

The colour indicates the enclosed fossils. Fronds of ferns and delicate plants give blue stems, and the larger parts of plants, when numerous, give black, whilst mineral remains, owing to the quantity of oil they contain, give hardness and blackness. The nodules are harder and contain most iron in the black shales.

There is no great upheaval in the district, but the strata tell us their ever-changing history as it went steadily on over a very long period of time.

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3. *Some Physical Properties of the Coals of the Leeds District.* *By* Benjamin Holgate, *F.G.S.*

The coals of this immediate neighbourhood have not been subjected to so many changes since their formation as have the coals of many other districts.

Again, the variety of ways in which coals are used in the district give us peculiar advantages in practically watching their behaviour under different conditions of combustion and distillation.

The temperature at which coals are burnt has much to do with that behaviour. Thus, some coals which give a warm glow leaving a dry ash when burnt at the low temperature of a house fire might not be the best suited for use in the furnace of a boiler, and still less so for use in a reverberatory furnace for the manufacture and working of iron, steel, or glass, in which case coal is burnt at a very high temperature. These coal seams are those of the upper part of the lower and the lower part of the middle coal measures, and they are exceedingly variable in their physical properties and in their behaviour during combustion.

There is the greatest difference between coals of different horizons even of the same seam. Some have the cleat or cleavage wide apart, and contain very little mineral charcoal; they have a brown streak, and are very hard, being of a dull black colour. If thrown to the ground they give a sonorous ring.

Immediately over or underlying these may be another coal with its cleat or cleavage very close, bright in appearance, easily broken, soft and light.

It is evident that these two coals, lying in the same seam and having been subjected to the same geological conditions and changes, must have been originally made of very different materials. Between these two we have many varieties. If we slice the dull black coal in a vertical section we shall find that we cut through numerous resinous spores. If without slicing we grind and polish it vertically we find the same resinous spores protruding in the polished surface. Again, if we fracture the coal we can see with the naked eye the spores standing out on the fractured surface; on the other hand the bright coals which break into smaller pieces cannot be sliced in sufficiently thin sections to be transparent. They contain more mineral charcoal, and from examination we may infer that they are made more of stems of plants than the others. This is still further proved by the examination of the baume pots which are found in the middle of coals of this kind. There are two coals, many feet apart, which have the same characteristics, namely, the 'better bed' and one portion of the 'Middleton little coal.' These are made up in a great measure of spores; their ash is not easily fused; they contain a very small proportion of sulphide of iron or other fusible salts, so that they are best for use under circumstances where the temperature is high.

The other coals, those with their cleat close together, when thrown upon the fire at once break down into small pieces which cool the fire, and by preventing the passage of a sufficient quantity of air are distilled more slowly and give off a different compound of gases from those given off by the coals with wider cleavage. This is the principal difference between a caking and a non-caking coal. They also contain a larger amount of sulphide of iron and different soluble and easily fusible salts, which go to make not only more ash, but ash of such a kind that it fuses and blocks up the spaces between the fire-bars, by this means preventing a more perfect combustion with our present rude methods of burning the coal. These fusible salts were not all present when the coals were originally placed where we find them, but they have been deposited by water since that time, and since the cleat was formed, for they lie in the thin interstices of the cleat. It follows then that there is more ash and more sulphur in coals having a close cleavage than in those in which the cleavage is farther apart. This has come about, first, through chemical changes in the different substances of which the coal was composed; secondly, the different forms which the coal has assumed in the geological changes that have taken place since; and it follows that we must look as much or more to the geological features as to the chemical ones for a right judgment as to the uses to be made of them for coking, gas-making, and for use in different kinds of fire-ranges and furnaces.

4. *On the Boulders and Glaciated Rock-surfaces of the Yorkshire Coast.*[1] *By* G. W. Lamplugh, *F.G.S.*

An enumeration and analysis of the larger boulders (those over one foot in diameter) which strew the cliffs and beaches of the Yorkshire coast have yielded interesting results bearing on the direction and character of the ice-flow.

Comparisons of the lists compiled at various widely-separated localities reveal points of agreement, and of difference, which are equally suggestive.

The following condensed table shows the chief features of these boulder-lists:—

Boulders over 1 foot in diameter. Origin.	South Holderness, near Withernsea. 500 boulders on the beach.	North Holderness, near Hornsea. 100 boulders in the cliff.	Flambro' Head, south side. 1100 boulders chiefly on the beach.	Filey, near the Brigg. 100 boulders in the cliff.	Cayton Bay, south side. 100 boulders in the cliff.	Robin Hood's Bay. 100 boulders in the cliff.	Whitby, north of Upgang. 200 boulders in the cliff.
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Carboniferous Limestone (including also a few other Palæozoic Sedimentary Rocks)	22·8	17·	23·3	13·	14·	13·	30·
Sandstones, Grit, Conglomerate, &c. (probably all, or nearly all, from Carboniferous or other Palæozoic Rocks)	14·4	45·	26·8	15·	25·	28·	18·
Mesozoic Rocks (Jurassic Limestones and Sandstones, Chalk, &c.)	22·1	22·	1·	51·	40·	48·	35·5
Basaltic and other Eruptive Rocks	37·3	14·	43·2	19·	18·	7·	15·5
Granite, Schist, Gneiss, &c. .	3·4	2·	5·7	2·	3·	4·	1·
Total	100·	100·	100·	100·	100·	100·	100·

Notes on the Lists.

Although there is usually some difference in the distribution of the various rocks at different horizons, these lists may be taken as indicating the relative proportion of the different rocks among the larger boulders contained in the whole mass of the drift. In two localities, however, where it was necessary to examine the boulders lying on the beach, it is probable that the proportion of the basaltic rocks has been unduly increased, and that of the sandstones diminished, through the differentiating action of beach-erosion.

In every case the proportion of boulders from the Carboniferous system is high, ranging from about 25 per cent. to as much as 60 per cent., or even more if the basalts, which must often have come from the same formation, be reckoned in.

[1] This paper formed the fourth of a series published in *Proc. Yorks. Geol and Polytech. Soc.* for 1887–9 and 1890.

Basaltic rocks of various kinds are usually very numerous. The far-travelled boulders of granite, gneiss, schist, &c., though never absent, are always in small proportion, generally under 5 per cent. It is, as might be expected, in the local Secondary rocks that the greatest differences occur; these are all but absent from the Flambro' Head list, while at Filey, only a few miles away, they comprise over 50 per cent.

A petrological examination of a selection of these boulders has been carried out by Mr. A. Harker, M.A., F.G.S.,[1] who finds that some of the igneous rocks are certainly—and others probably—from the south and west of Norway; while others have been derived from the northern and eastern parts of the English Lake District; from Teesdale; from the Cheviot Hills; and from the southern part of Scotland.

In discussing the theoretical bearing of these results, it is shown that they are consistent with the views, elsewhere expressed, that land-ice has moved southward over the bed of the North Sea, and, in doing so, has deflected and carried southward the glaciers which were streaming eastward from the Tees and other northern valleys, pressing them against the high eastern coast-line of Yorkshire.

A well-glaciated surface of Coralline Oolite recently discovered under the drift near Filey Brigg yields positive evidence as to the direction of the ice-movement, the grooves and scratches pointing N. 20° E. Also in several places on Flambro' Head the upper layers of the chalk are puckered up into sharp folds, which die out downwards, and these have evidently been caused by a force bearing from north to south across the surface.

5. *East Yorkshire during the Glacial Period.* *By* G. W. LAMPLUGH, *F.G.S.*

In this paper the author sums up his observations on the drift deposits of the Yorkshire coast. The marine beds of Sewerby and Speeton are placed at the base of the glacial series, and it is argued that the 'Basement Clay' registers the history of the first general glaciation of the area, which was wholly extrinsic, and in no degree dependent upon local accumulation.

The Basement Clay with its shelly inclusions (Bridlington Crag) is explained as the result of the encroachment upon the coast of land ice, which had gradually filled up the northern part of the bed of the North Sea. This ice carried forward portions of the sea-bed and became charged with marine débris. Off Flambro' Head it seems to have reached a thickness of about 500 feet, and the slope of its upper surface rose higher eastward. It slightly overtopped the chalk escarpment at Speeton, and gravels washed from its flanks were lodged on the crest of the Wold there, but the mass of the ice was deflected along the face of the cliffs.

The lower portion of the headland, near Flambro' village, was, however, completely overridden, and the ice passed across into Bridlington Bay. Holderness, at that time an open bay, was overwhelmed up to the slope of the Wolds, but the Wolds themselves remained bare.

The next stage, that of the 'Purple Clays' of Holderness, seems to have been marked by a general lowering of the surface of the ice and by wide oscillations of its margin, so that a large portion of Holderness was uncovered, as was also the ground at the foot of the Wolds and Moorlands. These areas received thick but irregular deposits of silt, sand, and gravel (often with a thin sprinkling of marine shell-fragments), derived partly from the surface drainage of the ice and partly from the bare land to the westward. Within the margin of the ice, however, the formation of boulder clay was still going on, and thus it is that much of the 'Purple Clay' of eastern Holderness is probably contemporaneous with the intermediate gravels of the interior and of the country north of Flambro' Head.

Then followed the period of the Upper Boulder Clay. This clay, which is inclusive of the 'Hessle Clay' of Messrs. Wood and Rome, is best studied north of the Wolds. Its source does not seem to have been quite the same as that of the Basement clay, the ice by which it was laid down coming chiefly from the high Carboniferous region in the north-west. If the glacier of the North

[1] Printed *in extenso* in *Proc. Yorks. Geol. and Polytech. Soc.* for 1889 and 1890.

Sea which formed the Basement clay had, at this period, so far receded as to leave a hollow between its western margin and the eastern moorlands, it is conceivable that the Teesdale glacier and other northern British ice may have crept down the valley, overriding the old moraine and all except the highest of the gravel mounds. It is suggested that the shrinkage of the extra-British ice concurrently with the increase of ice within our own borders, for which there is much evidence, may have been brought about by the shifting westward of the main area of snow precipitation, and therefore of ice formation, consequent upon the encroachment of the high plateau of the ice-sheet upon the surrounding seas and the wide obliteration of the open water-surface.

The Upper clay is often very loose in texture, and sometimes passes insensibly into sand and gravel, and it is possible that it may have been formed through the gradual melting of the icy covering and the resultant deposition of the insoluble residue, as suggested by J. G. Goodchild for the western drifts.

The arrangement of the Yorkshire drifts into Upper and Basement Boulder Clays, with an intermediate series consisting partly of stratified beds and partly of boulder clay, would remove many of the difficulties which have prevented their correlation with the glacial deposits of surrounding areas.

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6. *Final Report on an Ancient Sea Beach near Bridlington.*—See Reports, p. 375.

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7. *On Liassic Sections near Bridport, Dorset.* *By* JOHN FRANCIS WALKER, *M.A.*, *F.G.S.*

The author refers to descriptions by Day, H. B. Woodward, and Buckman, and then gives the results of his own observations in 1887 and 1888:—

(1) The roadside cutting in North Allington shows the following section in descending order: (*a*) clay, (*b*) stone 2 feet 4 inches, consisting of 8 inches white limestone, 1 inch clay, 11 inches pink limestone, 8 inches marlstone, (*c*) 3 feet 2 inches sandy clay, (*d*) 5 inches brown sandy limestone, (*e*) about 6 feet sandy marl obscured, (*f*) 2 feet 1 inch brown friable sandstone; the brickfield below contains another stone band embedded in clay with *Rhynchonella amalthei* and *Monotis inæquivalvis*. The stone band (*d*) contains fossils corresponding with those of the brown sandy limestone of the beach, *Rhynchonella tetrahedra* var. *Northamptonensis*, *Rh. furcillata*, *Waldheimia perforata* var., *Spiriferina pinguis*, *Monotis inæquivalvis*, *Pholadomya ambigua*, *Pleuromya* sp., *Belemnites*.

(2) In the field, opposite, the following section was exposed in 1887: soil 6 inches, (*a*) hard clay 2 feet, ferruginous marl 3 inches, (*b*) white stone and pink sandy stone 14 inches, marlstone 6 inches, (*c*) sandy clay. The pink rock yields *Rh. Bouchardii*, and in its upper part, *Ammonites striatulus*; the marlstone blocks yield *Rh. tetrahedra*, *Rh. fallax*, *Rh. serrata*, *Terebratula punctata*.

(3) A section at Shoots Lane, Symondsbury, somewhat overgrown, shows: (*b*) white and pink rock 18 inches, brown rock 2 feet 6 inches, (*c*) brown sandy clay 3 feet; the brown rock contains *Rh. serrata* in the upper part and *Rh. tetrahedra* in the lower.

(4) Information from the workmen, and measurement of the blocks removed, indicate that the following section was revealed at Shipton Long Lane, Bothenhampton, in a hole on the roadside, which was blasted for road metal and subsequently filled by order of the police: Unfossiliferous sandstone 4 inches, top bed of white stone 14 inches, brown stone 1 foot, brown and pink stone 2 feet, marlstone 1 foot, bluish unfossiliferous limestone 8 inches. The marlstone becomes more red towards the top, and is covered in some blocks by the pink rock, containing ferruginous oolitic grains, in others by a *sandy conglomerate*, which appeared to change gradually into the hard red (or in places cream-coloured) rock. The marlstone contains *Ammonites spinatus*; in its lower part are *Rh. tetrahedra*, *Rh. fallax*, *T. punctata*, *W. perforata* var., *W. resupinata*, (but no *Rh. acuta*); in its upper part

Rh. serrata is very abundant. The pink rock contains *Rh. Bouchardii, W. Moorei,* and in the conglomerate beds masses of *A. bifrons* in a pinky-brown ferruginous rock were the common fossils, but there were large *worn* specimens of *A. serpentinus,* and also in a creamy rock *A. crassus*; the brown and white stones have a *Rhynchonella,* somewhat like *Rh. jurensis* Quenst.; the brown rock contained *A. thouarsensis* d'Orb. = *A. striatulus,* and the white rock *A. Aalensis* Zieten *Germanii* d'Orb.

If this last section is correctly restored it corresponds with that at Ilminster, as far as the zone of *Rh. Bouchardii*; there is then wanting the *serpentinus* and the lower part of the *communis* zone, the fossils from which are deposited in the brown conglomerate bed of the age of *A. bifrons,* which is covered by the zones of *A. striatulus* and *A. jurensis.*

The brown conglomerate rock has been confounded with the brown marlstone in the blocks found on the sea-shore near Chideock, Dorset; and the fossils have been mixed.

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8. *On the Sounds known as the 'Barisál Guns,' occurring in the Gangetic Delta.* By T. D. LA TOUCHE.

The 'Barisál Guns' are sounds resembling the firing of heavy cannon at a distance. They are heard at various points in the Delta of the Ganges and Brahmaputra, and in the hills to the north of it; their origin has never been satisfactorily explained, though many theories have been advanced to account for it. Of these the principal are:—(i.) The breaking of surf-rollers during the South-west Monsoon on the shores at the head of the Bay of Bengal; (ii.) The falling in of high banks along the courses of the rivers in the Delta; (iii.) The firing of bombs by the natives at their marriage festivities; (iv.) Atmospheric electricity; and (v.) Subterranean or subaqueous volcanic or seismic agencies.

It is shown that none of these theories is entirely satisfactory, except, perhaps, the last; and that a cause of the sounds may possibly be found in slight movements of the layers of silt, composing the Delta, over each other, as they settle down; movements which may be augmented by the strains set up by the increase and decrease of pressure on the surface, due to the inflow and outflow of the tides along the river channels.

The paper concludes with a request for information regarding similar sounds, it it has been observed that any such occur in other large deltas.

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9. *On the so-called Ingleton Granite.*[1] *By* THOMAS TATE, *F.G.S.*

Under this commercial name a rock has recently been brought into the market as a road-metal.

It is quarried opposite Dale Barn, Ingleton, in the Borrowdale series, underlying the Mountain Limestone, forming Twistleton Scars on the north-west and Raven Scars on the south-east, extending thus quite across the valley, with a sharp dip to the south-west, for a thickness of about 400 yards.

This rock has been variously described by previous observers before the application of the microscope to its interpretation. It is a greyish-green quartzose volcanic tuff. No lapilli or any included fragments conspicuously exceeding the average are present. This marked uniformity in texture at each horizon—graduating from grains one-eighth of an inch down to the finest particles—points to the sorting action of gravity exerted upon materials in aqueous suspension. By the parallelism of the longer axes and the stratification arising therefrom, sedimentation is further in evidence.

The detritus of a quartzite has supplied most of the clastic elements; next to this come crystals of quartz and of felspars, both orthoclase and plagioclase, the latter being the more abundant relatively, in the finer-grained layers. Ancient lavas, both acidic and basic—devitrified spherulitic rhyolites and augite andesites—have contributed of their spoils. While the majority of the components have

[1] For full Report see *Proc. of Yorks. Geol. and Polytech. Soc.* vol. xi. (1891).

sharply angular outlines, some few are exceptionally well rounded and water-worn. These detrital products, enclosed in a volcanic ash matrix of a diabasic character, have consolidated into a tough rock of low specific gravity (2·693), possessing great tenacity of resistance to abrasion. With the exception of a few strain-shadows in quartz grains, the microscopic slides exhibited offer no suggestion of the ingredients having suffered from mechanical deformation; but in the quarry may be noted one or two examples of schistosity resulting from shearing, these being restricted locally to the proximity of shrinkage joints now filled in with quartz and an earthy, green, derivative product. Above and below, this rock shades off into indurated grey-green ash beds. Flakes and lenticular fragments of volcanic mud scooped off the old sea floor have been caught up in the superposed volcanic tuff near to the line of junction, and some of these entangled patches, when freshly exposed in the quarry, show a septarian arrangement internally, the outer portions flaking off along faces coated with a lustrous film, the inner surface subsequently weathering to a variegated dull purple or brownish tint.

The quarry may be inspected on the way to or from Ingleborough.

FRIDAY, SEPTEMBER 5.

The following Papers and Reports were read:—

1. *The Devonian Rocks, as described in De la Beche's Report, interpreted in accordance with Recent Researches.* By W. A. E. Ussher, *F.G.S.*

[Communicated by permission of the Director-General of the Geological Survey.]

Owing to the very complex association and variable characters of the Devonian rocks of the South-Western counties, the information gleaned by Sir Henry De la Beche, during a very rapid survey made more than fifty years ago, did not enable that eminent pioneer of Stratigraphical Geology to arrive at any certain conclusions respecting the relations of the strata composing the then-called Grauwacke System. The results obtained by a careful study of Chapter III., on the Grauwacke System, in De la Beche's Report, are most unequal.

Where the structure is comparatively simple, as in North Devon, the succession is given (pp. 45–56) in a plain and masterly manner; and although no classification is put forward, the strata are described in successive groups, each of which corresponds to a true subdivision. The grouping I have adopted for North Devon, by mapping out the subdivisions in the field, is De la Beche's grouping accentuated by names and geological boundaries. He applies the same grouping to West Somerset, where the structure is much more complex, and his correlations are correct. Sections I. and II., Plate III., are admirable illustrations of the succession of the Devonian subdivisions.

Turning to the intricate and involved region of South Devon (pp. 64–78), we find that the grouping is based on the assumption that strike-lines have the value of horizons, and thereby the South Devon limestones are made to occupy several distinct horizons in the slates. Although contemporaneous volcanic action is pointed out, yet the greatest tract of volcanic rocks in the whole region (*i.e.*, the Ashprington Series) is confounded (p. 76) with arenaceous rocks (now known to be Lower Devonian). Inverted junctions are regarded as natural junctions, as in the Plymouth succession (p. 65). As De la Beche's suggested correlations apply to an interpretation of this part of the area supplied by co-workers, the reader must not hold him in any way responsible for them.

The treatment of Cornwall differs from South Devon, with which it is in many places so interwoven as to render it difficult to follow the text. Here we appear to have the strivings of the great geologist to piece together and simplify the results of his direct personal observations. That he failed is due, not only to insufficiency of material, but to the absence of allowance for inverted junctions; again and again he is confronted with anomalous appearances of this kind, so that his correlations, always made with extreme caution and great ability, in some cases, when studied by transferring the information to a map, prove to be contradictory. Although much involved, De la Beche's descriptions of Cornwall seem to furnish some clue to the structure of that county, when interpreted by a comparison with the known regions of North and South Devon.

The following classification of the Cornish rocks is arrived at by an exhaustive study of De la Beche's Report, and by some years of hard work in the Devonian rocks of North and South Devon, supplemented by careful observation of the coast from Plymouth to Looe, and by traverses in the Launceston, Petherwin, and Tavistock country. These materials are sufficient to justify the classification as a suggestive and tentative one; beyond this nothing is attempted.

Upper Devonian.

Tintagel and Petherwin Series with contemporaneous Volcanic Rocks.—The major part of the series consists of grey slates, but red slates (St. Kew and St. Minver, St. German's and Mutley, &c.) seem to predominate in the lower beds.

Extent:—Pentire Point to St. Tudy and Egloshayle, and round the Camelford granite, between Tavistock and Plymouth.

Correlations:—With Entomis and Goniatite slates of South Devon. In the upper horizons, also with Livaton and Druid beds; with Pilton beds, Pickwell Down slaty horizons, and (?) Morte slates.

Middle Devonian.

Grey slates, with occasional limestone bands.

Extent:—From Permizen Bay, toward St. Tudy, and perhaps on north of St. Breock Down eastward to Warleggon, Mount Edgcumbe, Landulph Promontory on the Tamar, and probably elsewhere in the neighbourhood.

Correlations:—With slates between Plymouth and Totnes; with Ilfracombe series.

Lower Devonian.

Upper Coblenzian.—St. Breock Down and Boconnoc arenaceous beds, Picklecombe and Maker grits.

Correlations:—With Hangman series of North Devon; with Staddon and Cockington grits.

Lower Coblenzian.—Mawgan slates, Tregantle limestone, &c. (?) Newquay slates.

Correlations:—With Lynton beds of North Devon, Meadfoot beds of South Devon.

Hunsruckien (?)—Variegated slates of St. Austell, extending from Talland, by St. Blazey to St. Stephen's, and from Tregoss Moor to Watergate Bay.

Correlations:—With Dartmouth slates; (?) with Foreland grits.

Upper Gedinnien.—Looe Beds. Pencarrow and Gribbin Head, at the Black Head, and thence to the West coast near St. Cubert. If the Newquay slates do not belong to this horizon, the red slates of Watergate Bay would be in an anticline, and be represented in the area between Cubert and Newquay by a continuation of the St. Austell beds west from St. Stephen's.

Lower Gedinnien.—Grampound and Newlyn Down arenaceous rocks; possibly the base of the Devonian beds, and separating them from Lower Silurian rocks extending to the south of the latitude of Grampound.

The extension of the Grampound horizon south of Newlyn Down is inferred by De la Beche, but it is not noticed in his section from Newdowns Head to the Lizard (Plate II., Fig. 4). De la Beche correlated the Gorran limestones with those of the Looe beds, and regarded the red slates of Falmouth as a lower horizon than the St. Austell band.

The grouping south of Grampound may be inverted; in which case (1) slates, with occasional contemporaneous volcanic rocks of Penzance, Gwinear, perhaps Feock, might be uppermost, and in descending sequence therefrom (2) Falmouth slates, (3) Mevagissey slates, (4) Gorran, Veryan, Nare Head, and Porthalla beds.

2. *On Pre-Cambrian Rocks occurring as Fragments in the Cambrian Conglomerates in Britain.*[1] *By* Henry Hicks, *M.D., F.R.S., F.G.S.*

In this paper the author indicates by a table the contents of the basal Cambrian conglomerates in several areas in Britain, where he and others have claimed that Pre-Cambrian rocks are now exposed. He shows, on the authority of such eminent petrologists as Professor Bonney and Mr. T. Davies, that rock-fragments which have been collected from the conglomerates in various districts by Professor Hughes, Dr. Calloway, and himself, have been proved to be identical in character in the minutest microscopical details with some peculiar granitoid rocks, and some basic and acid volcanic rocks, schistose rocks and porcellanites, which have been described by them as Pre-Cambrian rocks in those areas. He further shows that in some places the conglomerate is almost entirely made up of rolled fragments from immediately underlying rocks. At Ramsey Island, and Treffgarn in Pembrokeshire, at Bangor, and near Llanberis and Bethesda in Carnarvonshire, where the Cambrian conglomerates rest on Felsites and old Rhyolites, more than three-fourths of the pebbles, which are frequently of very large size, have been derived from the immediately underlying rocks. Near St. David's, and at other places where the conglomerates rest on various altered volcanic tuffs, a large number of the pebbles have been derived from those tuffs after they had been cleaved and otherwise changed into their present condition. At Porthclais, Chanter's Seat, and Porth Melyn, near St. David's, a large number of the pebbles (mostly of small size) and the mixture of broken quartz and felspar, of which some of the beds are almost entirely composed, could only have been derived from the underlying granitoid rocks (Dimetian). The author shows that near Llanfaelog and Llanerchymedd, in Anglesea, very large pebbles of the underlying granitoid rocks are abundant in the overlying Cambrian conglomerates, and that at Twt Hill, near Carnarvon, the matrix and many of the pebbles must undoubtedly have been derived from the underlying granitoid rocks.

Table showing the rocks which have been found in the Cambrian Conglomerates in different areas.

Rocks	Pembrokeshire	Merionethshire	Carnarvonshire	Anglesey	Shropshire	Ross-shire	Sutherlandshire
Granitoid (Granite, Pegmatite, &c.)	×	×	×	×	×	×	×
Quartz porphyry	×	—	×	×	×		
Felsite	×	×	×	×	×		
Rhyolite, Dacite, and Andesite	×	×	×	×	×		
Diorite and Syenite	—	—	—	—	—	×	×
Diabase and Basalt	×	×	×	×	×	×	×
Gneiss	—	—	—	×	×	×	×
Sericite schist	×	×	×	×	×	×	
Chlorite schist	×	×	—	×	×	×	
Hornblende schist	—	—	—	×	—	×	×
Mica schist	×	×	×	×	×	×	×
Quartz schist	×	×	×	×	×	×	×
Volcanic fragmental (Acid and Basic)	×	×	×	×	×	×	
Porcellanite	×	×	×	×	×		
Clay slate	×	×	×	×	×	×	×
Quartzite	×	×	×	×	×	×	×
Sandstones	×	×	×	×	×	×	×
Calcareous	—	—	—	×	—	—	×
Ferruginous	×	×	×	×	×	×	×
Quartz, Jasper, &c.	×	×	×	×	×	×	×

[1] Published *in extenso* in *Geol. Magazine* for November 1890.

The author states that the so-called Torridon conglomerates and sandstones, in Ross and Sutherland, contain abundant evidences to show that most of the materials were obtained from the rocks upon which they now rest, after the latter had assumed their present condition.

He claims that the presence of pebbles of granitoid rocks, quartzites, quartz-schists, &c., in all the areas, proves clearly that some granitoid rocks were exposed to denudation on a large scale in many areas, in very early Pre-Cambrian times, for materials derived by denudation from the latter rocks must have been formed into quartzites, porcellanites, and schists (Arvonian rocks) in early Pre-Cambrian times. By subsequent denudation these yielded pebbles to the newer Pre-Cambrian rocks (Pebidian), and afterwards to the basal Cambrian conglomerates.

The author maintains therefore that the Pre-Cambrian rocks contain evidences of successive periods of elevation and depression, and probably of volcanic activity, and that the tendency of the evidence is undoubtedly to show that some of the granitoid rocks (Dimetian) are amongst the very oldest of the Pre-Cambrian rocks which are now found exposed, and that some quartzites, porcellanites, and schists occupy an intermediate position in age between these granitoid rocks and the Pebidian series. The Pre-Cambrian periods, therefore, which have been defined by the author by the terms Dimetian, Arvonian, and Pebidian, are easily recognisable whether the names be accepted or not.

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3. *The Effects produced by Earth-movements on Pre-Cambrian and Lower Palæozoic Rocks in some Sections in Wales and Shropshire.*[1] *By* HENRY HICKS, *M.D., F.R.S., F.G.S.*

The author in this paper gives examples to show the powerful influences exerted by earth-movements in producing changes in the rocks, and in obliterating the evidences of succession in the disturbed areas in Wales and Shropshire. He points out that the difficulties experienced by geologists who examine these areas for the first time are mainly due to their being unable or unwilling to recognise the extraordinary effects produced by these earth-movements, and especially the complications due to faults and thrusts. Frequently, he says, portions of the Pre-Cambrian rocks have been forced in among the Lower Palæozoic rocks so as to appear either to be parts of the series or to be intruded into it. In other places they have been made to appear to overlie much newer beds. A section across the St. David's promontory shows an arch of Cambrian rocks, and of Arenig beds containing great masses of igneous rocks, probably portions of sheets in the forms of Laccolites, all bent over a core of Pre-Cambrian rocks, and repeatedly broken on the west side by thrust-movements, causing newer beds to be driven over beds of various horizons, in some cases many thousands of feet apart in the succession; whilst on the east side the limb is broken by reversed faults, so as to make the beds appear to dip under the Pre-Cambrian rocks. Again, in the Pre-Cambrian core itself the Pebidian rocks are not only sheared to an enormous extent, but are also made, on the south side, by reversed faults, to appear to lie under parts of the granitoid rocks (Dimetian); one result of these mechanical movements being to make the Dimetian look as if intruded into the Pebidian beds, whilst in reality it is everywhere here bounded by faults, as the result of repeated earth-movements in Pre-Cambrian and subsequent periods. The author also shows that very similar results have taken place in the sections between the Menai Straits and the Snowdon district, where not only do the Cambrian rocks appear to underlie the Pre-Cambrian, but at one point even Arenig beds are made to dip under both.

The author states that in a section in Shropshire, extending from the Longmynd across Caer Caradoc, Lower Palæozoic rocks are faulted so as to appear to underlie the Pre-Cambrian rocks of Caer Caradoc; whilst on the east of Caer Caradoc, as the result of thrust-movements, great thicknesses of the lower beds have been hidden by much newer ones. He mentions that the changes which have been produced in the rocks themselves are also very marked. The granitoid rocks give

[1] Published *in extenso* in *Geol. Magazine* for December 1890.

evidence of having been greatly crushed by the earth-movements in Pre-Cambrian times, and in the lines of fracture secondary minerals have been freely deposited. That these secondary minerals date back to Pre-Cambrian times is shown by the fact that the pebbles of these granitoid rocks in the Cambrian conglomerates contain all the evidences of the early crush with secondary minerals in the crush-lines, in addition to those of subsequent fracture and deformation by pressure after they had been entombed in the conglomerates. Some of the felstones in Pre-Cambrian times were crushed so that they were formed into felsitic schists, and fragments of these schists occur frequently in the Cambrian conglomerates. Various dykes in the Pre-Cambrian rocks exhibit indications of having suffered greatly from mechanical pressure in Pre-Cambrian times, the diabase dykes in the Dimetian being frequently cleaved so as to look almost like slates. Fragments of these and of many other cleaved and altered rocks occur frequently in the Cambrian conglomerates. In the Cambrian and Ordovician rocks the evidences of pressure during subsequent earth-movements are also abundant, and secondary minerals have been freely developed along planes of cleavage and in lines of fracture. The effects on some of these rocks near thrust-planes are well exemplified by the remarkably distorted condition of some of the fossils. In Tremadoc beds, near St. David's, an *orthis*, which in its normal condition was about 7 lines in width, was so distorted that it measured over 27 lines, and others were still further drawn out so as to be almost unrecognisable.

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4. *On the Mineral Resources of New South Wales.* *By* C. S. Wilkinson, *F.G.S.*

In this paper the author described the economic geology of the colony of New South Wales. This territory occupies the central portion of eastern Australia, and has a frontage to the Pacific Ocean of 850 miles, with Port Jackson, or Sydney Harbour, situated midway along this coast line. It is remarkable that all the chief characteristic physical features of the great island-continent of Australia are represented in New South Wales. The Cordillera, or Main Coast Range, culminating in Mount Kosciusco, the highest mountain in Australia (7,176 feet), and snow-clad during many months of the year, extends through the colony from north to south; the largest Australian river flows through the vast delta-plains and almost treeless downs of the western interior; the Cordillera, especially on its eastern slopes, is in places clothed with dense forests of the finest timber trees, and the coast is indented with several splendid shipping ports. The geological features of the colony embrace nearly all the principal sedimentary and igneous formations of the Old World series, from the Silurian upwards; and in these occur, in more or less abundance, most of the commercially valuable mineral products:—*Coal, gold, silver, lead, tin, copper, antimony, iron, manganese, chromite, bismuth, alunite, diamonds, marbles, clays,* &c. From the Cretaceous formation of the arid downs of the western interior fresh *artesian* water is obtained by boring. New South Wales, therefore, favoured also with a splendid climate, possesses natural resources of great significance for the future development of the mining, agricultural, and other industries.

The total value of the minerals raised in New South Wales to the end of 1889 is 81,598,113*l.*

Coal.—The Coal Measures are of Carbonifero-Permian age, and occupy an area of about 24,000 square miles. There are three main series:—The Lower Coal Measures, consisting of plant-beds interstratified with beds containing a Carboniferous marine fauna; and the Middle and Upper Coal Measures, consisting also of plant-beds. *Glossopteris* is one of the characteristic fossil plants found in each of these series. The aggregate thickness of coal in the seams worked is about 130 feet. One seam lately discovered near West Maitland by Mr. T. W. E. David, Geological Surveyor, is over 30 feet thick. Coal was first worked in the colony in the year 1830, though discovered about 1796. The value of the total quantity raised to the end of 1889 is 22,787,155*l.*, the production for the year 1889 being 3,655,632 tons, valued at 1,632,848*l.* Several seams, up to 5 feet thick, of *Petroleum-oil Cannel coal,* or '*Boghead mineral,*' occur in the Coal Measures. This so-called 'Kerosene Shale' is the richest of the kind found in the world, and yields up to 150 gallons of crude oil, or 18,000 cubic feet of gas per ton, with an illuminating power equal to over forty candles.

GOLD.—Gold has been worked from reefs and the alluvial deposits derived therefrom. The reefs occur in the Silurian, Devonian, and Carboniferous strata; also in granite, porphyry, diorite, serpentine, &c. The auriferous alluvial deposits resulting from the denudation of these, are found in the Carbonifero-Permian, Cretaceous, Eocene, Miocene, Pliocene, Pleistocene, and Recent formations. Gold with platinum has been obtained in the débris from basalt. Gold was discovered in 1851, and the total yield to the end of 1889 is 10,092,355 ounces, valued at 37,614,887*l.* Numerous gold-bearing reefs, as yet undeveloped, are known to exist. With proper appliances for extracting gold from sulphides, &c., its output is likely to largely increase.

SILVER AND SILVER-LEAD.—The lodes containing these metals chiefly occur in the Silurian and Devonian formations and in the igneous rocks (chiefly granites), intruding them. The most important lode yet opened is at Broken Hill. It is a fissure-lode consisting of gossan with manganese, carbonate of lead, and sulphides of lead, iron, and zinc. The Broken Hill Proprietary Company's Mine on this lode has yielded since May 1886 to July 1890, 17,457,279 ounces of silver from 385,880 tons of ore treated, besides a large quantity of lead. The silver lodes at Gunny Corner, Captains Flat and Costigan, contain also a fair quantity of gold. There are numerous small lodes to be developed. The value of the silver and silver-lead produced in the colony to December 31, 1889, amounted to 4,909,952*l.*

TIN.—The ore of this metal has chiefly been worked as stream-tin from the Tertiary and Recent alluvial deposits. The Tertiary deep leads, or ancient river-beds, as yet unworked, are extensive. Numerous tin-bearing lodes have been discovered in the granites of New England and the Barrier Ranges, but they have only been slightly worked. The value of the production of tin and tin ore to 31st December, 1889, amounted to 8,925,543*l.*

COPPER.—Copper lodes have been opened in various parts of the Colony in the Silurian and Devonian formations, and are capable of being further extensively worked. At the surface they consist chiefly of gossan containing rich carbonates of copper, which pass downwards into sulphides of copper and iron. The value of the total production to the end of 1889 is 5,645,027*l.*

ANTIMONY.—The principal antimony lodes occur in association with dykes of granite traversing Devonian strata. Stibnite and Cervantite are found occasionally in many quartz reefs. At Hillgrove, in New England, and at Razorback, the antimony lodes contain payable quantities of gold. In the New England and Macleay districts the development of auriferous antimony mines will probably be very important. The value of antimony exported to December 31st, 1889, is 73,501*l.*

IRON.—Deposits of brown hematite and magnetite occur in numerous localities, and, in places, in proximity to coal and limestone. The deposits at Mittagong have been estimated to contain, within a radius of five miles, about 2,872,000 tons of ore in sight. In the district traversed by the Great Western Railway line the deposits of ore are, perhaps, more extensive; and near Stroud and Musclebrook there are beds of rich magnetite, containing, however, some titanium.

CHROMITE, COBALT, MANGANESE, BISMUTH, AND MERCURY.—Ore deposits of these minerals have been opened in several parts of the Colony, but only worked as yet on a small scale; they deserve greater attention than has hitherto been bestowed upon them.

WOLFRAM, SCHEELITE, and BLENDE occur in several localities in some quantity, and will in the future be probably worked with profit.

ALUNITE.—A rich deposit of this mineral has been recently opened near Stroud for the manufacture of alum.

DIAMONDS AND OTHER GEMS.—Upwards of 50,000 diamonds have been obtained from the Tertiary and Recent drifts in the Bingera, Cope's Creek, Cudgegong, and Mittagong districts. The largest diamond weighed about $5\frac{5}{8}$ carats. With efficient appliances, the diamond mining industry is likely to become a profitable one in New South Wales. Sapphires, topazes, beryls, garnets, and zircons are of frequent occurrence.

BUILDING STONES, MARBLES, SERPENTINES, POTTERY, and BRICK CLAYS occur in abundance, and of excellent quality. Full particulars are given in the reports of the Department of Mines, Sydney, and samples of all the above-mentioned minerals were exhibited in the New South Wales Court in the International Mining Exhibition at the Crystal Palace, London.

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5. *Eighteenth Report on the Erratic Blocks of England, Wales, and Ireland.*—See Reports, p. 340.

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6. *On the Glacial Phenomena of the Isle of Man.* *By* P. F. KENDALL.

The author briefly referred to the work done by Strickland, Forbes, Cumming, Clifton Ward, Horn, and Hewitt, and proceeded to give some details of the distribution of the deposits.

The Ramsey Brooghs exhibit a section showing two beds of boulder clay separated by a bed of false-bedded sand.

Beyond the Dog Mills a section is exposed showing a great series of shingly and sandy beds, which the author regards as a true beach. These deposits cannot be with certainty correlated with the Ramsey series, but the author regards them as probably superior to them.

The cliffs attain an altitude of 200 feet, and extend for several miles. Beneath the beach series a very rich deposit of shelly clay is exposed, which has yielded many remarkable shells.

At the mouth of Ballure Glen a section is visible which shows a varied series of glacial deposits bedded at a high angle against the clay slate.

The cliffs near Kirkmichael are similar in character to those near the Dog Mills. Near St. John's a deposit of shell-bearing sands occurs.

In the south of the island many good exposures of boulder clay are visible, and in several cases a striated surface of limestone is to be seen.

Dr. Tellet quotes a statement by Campbell of Islay to the effect that a gravel bed containing scratched stones occurs on Snaefell at an altitude of 1,400 feet.

The Source and Distribution of the Erratics.—In the glacial tract of Ramsey and Kirkmichael Skiddaw slates, Carboniferous limestone, Red sandstones, and breccias and flints are abundant; and the author identified many granites, &c., from the south of Scotland, and the Eskdale granite. He could not find a single example of the Manx igneous rocks.

In the south of the island Cumming had shown that local rocks were abundant, and had a well-defined trail coinciding with the direction of the striæ. The foreign stones were similar to those found in the northern deposits. Boulders of the granite of Foxdale have been found lifted 800 feet above the natural outcrop in a distance of two miles. It is remarkable that no foreign stones occur at high altitudes in the island.

Palæontology.—The author refers to the work of Strickland and Forbes, and criticises their lists.

He identifies the *Nassa Pliocena*, Strick., with the *Nassa serrata*, Brocchi.

Fusus Forbesi, Strick., he holds to be distinct from the American *F. cinereus*, Say.

The author's own collections from the island include *Cemoria noachina*, and many other shells not commonly found, but the most remarkable find is that of *Columbella sulcata*, Sow. (by Mr. Kermode). It is a characteristic Red-Crag species like *Nassa serrata* and *N. Monensis.* It may be that these shells and the mollusca of southern range which occur in the Lancashire Drift are of *remanié* origin.

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7. *On the Speeton Clays and their Equivalents in Lincolnshire.* By G. W. LAMPLUGH, *F.G.S.*

In a recently published description of the Speeton section,[1] the author, after showing that the accepted classification of the Lower Cretaceous beds had been vitiated by misunderstandings as to certain parts of the series, proposed a re-classification, based on the Belemnites, which are the most abundant and most characteristic fossils.

Fresh evidence is now brought forward in support of this suggestion; and the zones adopted at Speeton have been traced in beds of the same age in Lincolnshire. The escarpment in the neighbourhood of the abandoned Acre House ironstone mines affords the most convenient sections, and the following correlation is based chiefly on the fossils collected there:—

Speeton: Yorkshire.	Acre House: Lincolnshire.
Red Chalk	Red Chalk
Zone A.—Marls, with Bel. minimus	Carstone
Zone B.—Zone of Bel. semicanaliculatus (?)	Tealby Limestone
Zone C.—Zone of Bel. jaculum	Tealby Clay
Zone D.—Zone of Bel. lateralis, including (E) Coprolite Bed	Claxby Ironstone Spilsby Sandstone
Zone F.—Bituminous Shales; (Upper Kimeridge of English geologists)	Upper Kimeridge Shales

NOTES.

F. *Bituminous Shales.*—These undoubtedly Upper Jurassic beds give a good base for the correlation. In spite of the limited nature of their fauna, the separate areas have yielded several characteristic species in common. It is probable, however, that the topmost layers of the division (which in Yorkshire contain a long Belemnite allied to *Bel. Owenii, Pratt.*) are wanting in most, if not in all, of the Lincolnshire sections through the overlapping of the Spilsby sandstone.

D. *Zone of Bel. lateralis, Phil.*—This zone deserves close consideration because of the recently-discovered analogy between it and the 'Upper Volga' beds of Russia, and because of the doubts which exist as to its precise age. At Speeton it has yielded certain fossils which have been supposed to be Portlandian forms, thus bearing out its stratigraphical position; but on the other hand it has also yielded numerous species usually referred to the Lower Cretaceous or Neocomian epoch.

In Lincolnshire the zone comprises both the Spilsby sandstone and the Claxby ironstone, which, contrary to the accepted practice, and in spite of their lithological difference, should be thus united, on the palæontological evidence. The Claxby ironstone may be correlated with the upper beds of the zone at Speeton as low as D 4,[2] and the Spilsby sandstone with the lower beds. The zone contains a more numerous and varied fauna in Lincolnshire than in Yorkshire.

[1] On the Subdivisions of the Speeton Clay: *Quart. Journ. Geol. Soc.* xlv. p. 575.

[2] These letters and figures are those used for distinguishing the different zones in the above-cited paper on the Speeton Clays.

C. *Zone of Bel. jaculum, Phil.*—In contrast with the preceding, this zone is feebly developed in the Acre House section, as compared with its great thickness and variety of fauna at Speeton. The Tealby clay falls wholly within the zone, but may represent only the upper portion of the Yorkshire section. It is possible that the top of the ironstone may in some place reach up into this division, but further research is needed.

B. *Zone of Bel. (semicanaliculatus?)*—The Upper, or Tealby, limestone in the neighbourhood of Normanby and Tealby contains many of the characteristic fossils of the lower part of the zone of Bel. (semicanaliculatus?), but it is not yet possible to say to what height in the Speeton section this correlation should be extended.

Consequently nothing definite can be stated with regard to the beds overlying the limestone, in which fossils are all but absent, but it is believed that the Carstone may have its partial equivalent in the marls (A) at the base of the Red Chalk at Speeton.

The paper concludes with some palæontological notes on the Speeton beds, based chiefly on a re-examination of the old collections; and with arguments derived from these notes as to the age and relations of the series.

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8. *On the Neural Arch of the Vertebræ in the Ichthyosauria.* *By* Professor H. G. Seeley, *F.R.S.*

The author described the vertebræ of Ichthyosaurs and showed, on the evidence of specimens in the British Museum and that of A. N. Leeds, Esq., that the neural arch has no zygapophyses or zygapophysial facets, but that there is a single flat median facet of vertically ovate form above the neural canal back and front, which is termed a proto-zygapophysis. The character has been found in many species from the Lias and lower Oolites, and in Ophthalmosaurus from the Oxford clay.

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9. *On the Marbles and other Ornamental Rocks of the Mediterranean.*[1] *By* W. Brindley, *F.G.S., F.R.M.S.*

White marbles only were used by the Classic Greeks, this material as a superior building stone being the most plentiful, and no doubt its purity had great influence on the refinement of their architecture, colour afterwards being applied to reduce its dazzling brightness. The Romans, following the Greeks, endeavoured to get lasting colour effect by the use of coloured marbles, every shade of which was found on the shore of the Mediterranean Sea. The Greek quarries of Pentelicus and Paros were very extensive, and are still workable. Under the Roman Empire there does not appear to have been any workable rock, even in the most remote spots. They did not find and transport to Rome. From Carystus in Eubœa were taken the Cipollino monoliths of the Temple of Antoninus and Faustina. The shores of Thessaly and Magnesia supplied the various greens; Synnada, the choice Pavonazzetto Antico, used in the Pantheon: these quarries, sixteen in number, have just been rediscovered, and are workable. Those of Giallo Antico in Tunis, the ancient quarries of Numidia, are now extensively worked. The quarries of Rosso Antico and Green Porphyry are in Laconia.

Down the Nile was brought the Oriental alabaster, the granite monoliths of the portico of the Pantheon and Forum of Trajan. Also down this river came the most sumptuous decorative stone the world has ever known, namely, Imperial Red Porphyry; blocks, 20 tons in weight, were procured, as seen in the Vatican. These quarries are now being reworked, and 280 small blocks from them have just arrived in London, many of which show the old methods of working, namely, splitting with wedges, scappling into rough shapes with hammers, rough and smooth pickaxed dressing, and truthfully sawn faces 2 feet in length. The coast of

[1] Published in full in the *Builder*, September 20, and the *Building News*, September 19, 1890.

Algeria and Tunis abounds with choice marbles, the richest of which are those of Kleber, near Oran. The Mediterranean coast of Spain is nearly one continuous mass of marble, producing whites of excellent quality, which were used for building the Alhambra, and also all shades of reds, yellows, and greens.

Rich red marbles of all sorts and mixtures are also found near the French coast of this sea. Italy is now the chief marble-producing country of the world; the quarries of Carrara and Monte Altissimo Serravezza produce more annually than all the rest of the quarries put together, and the various islands of this country possess valuable quarries, those of Sicily being of especial value.

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10. *The supposed Volcanic Eruption of Cape Reykjanæs.* *By* Tempest Anderson, *M.D., B.Sc., and* H. J. Johnston-Lavis, *M.D.*

It is currently believed in Iceland, and was stated in some of the public prints at the time, that a volcanic eruption or earthquake had taken place at Cape Reykjanæs in October 1887, by which a large new Giá or chasm had been formed separating a large rocky promontory, almost deserving the name of a mountain, from the main Cape on which the lighthouse stands. This chasm, at least 50 feet wide, was pointed out to the authors from a passing steamer, the captain declaring he remembered the rocks before they were rent asunder. Here, then, appeared a case of the formation of one of the Giás or chasms which form such a characteristic feature of Icelandic geology. There are several such on the Reykjanæs peninsula, huge chasms, several feet wide and of unknown depth, stretching for miles across the lava deserts of which the district is composed. In this district they usually, though not always, have a throw of a few feet or yards, but one of those at Thingvalla, more in the centre of the island, the Allmanagiá, has a throw of about 100 feet. In this instance the authors are satisfied that the Giá is due to the unequal settling of a crust of lava, formed on the surface of a still fluid mass, which has found an outlet and flowed out after the solidification of the surface. They are not prepared, however, to say that this explanation will hold in the case of all the rifts on the Reykjanæs peninsula. Consequently, any clear case of the formation of a fresh Giá in strata long cooled and solidified would have been of great theoretical importance.

From a careful examination of the locality it appears that no formation of a fresh Giá has taken place, but that certain small portions of the rock on which the lighthouse stands have been loosened, partly by ordinary denudation and partly by earthquakes, which are frequent here, and fallen on to the beach. The strata of partly consolidated volcanic ash, &c., are quite continuous in the end of the small cove or recess between the two large rocks above referred to.

Photographs were shown on the screen illustrating these points and showing several real and spurious rifts, and the structure of the lighthouse rock, which is the remains of a dissected volcano.

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11. *On Lepidophloios and Lepidodendron.* *By* Wm. Cash, *F.G.S., F.L.S., F.R.M.S., and* Jas. Lomax.

The genus *Lepidophloios* appears to have been established by Sternberg at a time when our knowledge of Carboniferous plants was based, for the most part, upon merely superficial characters and not upon the anatomical structure of the plants themselves. The two genera, *Lepidodendron* and *Lepidophloios*, though long known to hold close affinities, are clearly separated by well-marked characters.

In *Lepidodendron* the leaf-cushions are fusiform or quadrate, varying much in form, even in the same species, according to their position on the stem and conditions of growth. Situated on the cushions and generally above the centre is the leaf-scar proper, whose upper and lower boundary lines are usually more or less convex and unite in lateral angles. Within the leaf-scar are three punctiform cicatricules, the central of which is alone connected with the vascular system, the two lateral being probably glandular. The cones in some species are borne at the terminations of the branches, and in others in two opposite vertical rows (Ulodendron, L. and H., *in part*).

In *Lepidophloios* the leaf-cushions are rhomboidal (as in *L. laricinum*) or elongated-truncate (as in *L. scoticum*), and the leaf-scar is situated at the extremity of the cushion, having three punctiform cicatricules as in *Lepidodendron*. The cones are borne on specially modified branches and are arranged in spirals (*Halonia*, L. and H.).

The two genera are therefore very distinct in the position of the leaf-scar on the cushion, as also in their mode of fructification. The knowledge obtained of the structure of *Lepidophloios* since Sternberg's time, and especially that acquired in recent years, has confirmed the view of its close affinity with *Lepidodendron*.

Williamson has described the twigs, branches, stems, and fruits of *Lepidophloios brevifolium* from Burntisland, and has shown that, fundamentally, these have the structure of the same parts of *Lepidodendron*.

Solms-Laubach, in his 'Einleitung in die Paläophytologie,' states that Corda's *Lomatophloios crassicaule* has a structure similar to that of the true *Lepidodendron Harcourtii*.

Inasmuch, however, as Corda's genus *Lomatophloios* is Sternberg's *Lepidophloios*, there is sufficient justification for his conclusion that the structure of *Lepidodendron Harcourtii* may occur in *Lepidophloios*.

Further, the same authority states that the plant described by Williamson as *Lepidophloios brevifolium* is intermediate in structure between *Lepidodendron Harcourtii* and *Lepidodendron vasculare*, Binney (*L. selaginoides*, Carr and Will.). Its primary xylem has *not* the crenulated outline of the former species, though its structure is the same, but its leaf-trace bundles run downwards with only a slight projection, as in the latter. It further agrees, he adds, with the latter in the massive development of its secondary xylem. To these proofs of the near relation of the two genera under consideration, we are in a position to add yet another, drawn from a specimen which we discovered some short time ago. This consists of a fossil stem whose external surface is marked by tolerably well-preserved characters, which leave no doubt that it must be referred to the genus *Lepidophloios* as defined by Sternberg.

Transverse sections of it show, however, that in internal structure it is identical with the plant described by Williamson in his XIth memoir as *Lepidodendron Harcourtii*, but since named by him *Lepidodendron fuliginosum*.

The primary xylem has an outer periphery *slightly* crenulated, is in the form of a thin, hollow cylinder, and encloses a tolerably large pith composed of thin-walled parenchyma. Surrounding the primary xylem is a zone of dark, indistinct tissue in which are radially disposed elements, and which Williamson regards as the exogenous zone (secondary xylem) in an immature condition. Outside this is the thick cortex, which, in its general appearance as well as in the structure and the arrangement of several layers, is in close agreement with that of *Lepidodendron fuliginosum*.

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12. *On the Changes of the Lower Carboniferous Rocks in Yorkshire from South to North.*[1] *By* J. R. Dakyns.

The author describes, without going into details, the chief changes which the rocks undergo from south to north. These may be summed up as follows:—

1. The simple fourfold division of the Millstone grit prevalent in Derbyshire, ceases to be applicable northward, owing to the setting in of several fresh sandstones.

2. The Yoredale type of beds can hardly be said to exist south of Kettlewell. From Grassington northwards the carboniferous limestone becomes split up with beds of sandstone and shale, and north of Kettlewell important rocks, to wit the Underset and Main limestone, set in among the limestone shales, so that finally we have in Yoredale the well-known type of beds that go by that name.

3. In the southern part of its course the Main limestone is immediately overlain

[1] This paper is to be published in the *Trans. of the Yorks. Geol. Soc.*

by the Millstone grit, but northwards a set of cherty beds comes in between the limestone and the Millstone grit; this begins at Coverhead merely as a thin cherty top to the limestone, but the chert gradually develops into a series of cherty beds, sandstones, and shales, known as the Black and Red Beds in Swaledale. Still further north the cherty beds change into a set of coal-bearing sandstones, grits, and shales, known as the Coal Sills, overlain by a thin but persistent bed of limestone, known as the Little Limestone.

4. Owing to the deterioration of the lowest Millstone grit in Walden, Coverdale, and on the flanks of Penhill, it is somewhat uncertain what line should be taken further north as the Millstone grit base, so as to keep to the same horizon. In the author's opinion the best line (at least the most certain line) to take is the top of the cherty series and its equivalent the Little Limestone. Thus we shall, at all events, keep to one and the same horizon.

5. It is important to notice that the siliceous grits and ganister-like beds that occur in the Millstone grit series above the Kinderscout grits, become more pronounced northwards, so that at length they become regular ganister measures similar to the ganister measures of the lower part of the Coal Measures.

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13. *Human Footprints in recent Volcanic Mud in Nicaragua.* *By* Dr. J. Crawford.

In this communication the author refers to an article in the Proceedings of the Victoria Institute for 1889, reprinted from letters by Dr. E. Flint, and comments thereon by Dr. D. G. Brinton, published by the Philosophical Society of Philadelphia. Footprints of men and of wild and domestic animals occur on a bed of volcanic mud, now much hardened and overlain by alternations of finer and coarser consolidated ashy muds derived from volcanoes, near Lake Managua. The footprints are of Indians, with short, broad feet, evidently hastening towards the lake. The bed containing them rests on a yellow (so-called Miocene) sand, really a consolidated mud similar to those which overlie it, and the whole series of beds for at least 10 feet below the bed bearing the footprints is of recent date. The author, in illustration of the formation of volcanic muds, instances the great 'Aluvion de Barro' of 1876, which covered the Plaza grounds in Managua to a depth of 5½ feet, and also filled up the street previously called Calle Honda (deep street), which was 3 feet below the surface north and south of it, so that it is now a very important street, on the same level as the adjoining part of the city, and called Calle Mercado.

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14. *On the Geology of Nicaragua.* *By* Dr. J. Crawford.

The author divides the country into five areas for geological purposes:

I. A western section, roughly parallel to the Pacific coast, and including the large lakes Managua and Nicaragua, and several smaller crater lakes, some of which are filled with fresh water, while others contain large proportions of salts. The strata are mainly volcanic ashes, marine and lacustrine beds, with shells, and some deposits like glacial drift. The following heights are given:—

> Volcanoes: Viejo, 6,160 ft.; Momotombo (smoking), 6,510 ft.; Cosequina, 3,860 ft.; Masaya (large crater), 3,800 ft.; Mombacho, 5,100 ft.; Ometepa (hot top), 5,800 ft.; Madera, 5,000 ft.
>
> Lakes: Fresh-water—Managua, 123 ft.; Tiscapa, 176 ft.; Masaya, 215 ft.; Apoyo, 85 ft. Slightly saline—Nicaragua, 106 ft. Saline—Nejapa, 168 ft.; Giloa, 138 ft.

None of the volcanoes is now active, but there are boiling springs and old floods of mud, 'aluviones,' which mimic older stratified deposits.

II. A section north-east of the last consists of Recent delta deposits, Post-Glacial brick-earths and cave deposits, Pliocene, Miocene, Eocene, Cretaceous, Wealden, Oolitic, Permian, and Carboniferous rocks. In this section are found reptile and other bones, bituminous coal, copper, silver, and iron ores, but there are no craters, lakes, or mineral springs.

III. A band of gneiss, granite, slates, crystallised limestone, and iron ores of Archæan and Silurian ages, intersected by dykes and lodes carrying gold, silver, lead, &c. In these rocks are large caves in which human crania and other fractured bones of Neolithic or earlier date are found. There are cold and hot mineral springs but no volcanoes in this section.

IV. A narrow strip adjoining the last, and quite similar to section II., except that the rocks have not been so much disturbed. This section contains several gold placer mines—the beds of large early quaternary period rivers—some of them rich in gold; for example, the old river bed near to and on the north side of the present epoch river Prince Apulca.

V. A zone 80 to 100 miles wide, adjoining the Caribbean Sea, consisting of lagoons, swamps, and deltas, with a raised bed of sand. Mounds occur in this section containing stone hatchets, flint arrow-heads and spear-heads, and bones of man older in date than the Spanish occupation.

MONDAY, SEPTEMBER 8.

The following Papers and Reports were read:—

1. *Preliminary Note on the Composition and Origin of Cheshire Boulders. By* J. COUTTS ANTROBUS, *M.A., and* FREDERICK H. HATCH, *Ph.D., F.G.S.*

During the past twenty years a great number of boulders have been collected by the first-named author within a two-mile radius of Eaton, near Congleton. A microscopic examination of thin sections made from specimens of these boulders has been productive of interesting results, and has given certain indications of the sources whence the ice-borne boulders have been derived. The specimens examined constitute a fair average of the boulders as they occur, with the exception perhaps that the sedimentary rocks have been somewhat neglected as compared with the igneous samples. Of 68 specimens examined, 38·2 per cent. were granites, microgranites, and granophyres; 41·2 per cent. were volcanic (lavas and tuffs); 13·2 per cent. were sedimentary (quartzites); while 7·4 per cent. remained undetermined. Of the granites, &c., 13·2 per cent. were assigned to the Lake District, four specimens being identified as Muncaster granite and five as Buttermere granophyre; the rest are derived from the South of Scotland, and possibly the Western Isles of Scotland.[1] Shap granite, so abundant in the more easterly counties, was not found in the district under examination. The volcanic rocks are represented by types of lava, breccia and tuff, familiar to the student of Lake District geology. They belong to the Borrowdale Volcanic series. Eight specimens were found to be andesite; seven specimens rhyolite, and thirteen breccia or tuff. One specimen of gabbro and one of basalt are identical with those of the Western Isles of Scotland or of Antrim. The quartzites appear to be derived from the Ganister beds of the Carboniferous system.

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2. *On some West-Yorkshire Mica-trap Dykes. By* FREDERICK H. HATCH, *Ph.D., F.G.S.*

These notes refer to the petrographical character of the mica-trap dykes which are so numerous in the neighbourhood of Sedbergh, where they occur traversing rocks chiefly belonging to the Coniston Limestone series. They are fairly compact rocks, usually varying in colour from almost black to light-grey, but occasionally they are of a reddish-brown, or even of a cream colour. Their most constant

[1] Comparisons with the rocks from these districts have yet to be made.

feature is an abundant brown mica, dispersed through the rock in lustrous plates. In some cases these are of considerable size; in most of the rocks, however, they sink to minute specks, which are present in considerable number and give the rock a glittering appearance.

These notes are based on work done by the author for the Geological Survey. The specimens were collected by Mr. Strahan and himself in the summer of this year, and full details of their investigations will be published in the Survey Memoir on Sheet 97, N.W., now in course of publication. Sections for the microscope were made from dykes in the following localities: Backside Beck, west of the volcanic series; dyke in Wattle Gill; dyke in the Rawthey at Ward's Intack; dyke in Taith's Gill, 200 yards north of Fox Hole Rigg; dyke in Backside Beck, 100 yards north of the Wandale Fault; dyke at base of first felsite, Backside Beck; dyke near the foot of Wattle Gill; dyke in shale near the topmost felsite, Wattle Gill; dyke 300 yards west of Rawthey Bridge.

Under the microscope the mica sometimes appears in regular six-sided plates, but more frequently in ragged patches and blades. It is a dark-brown biotite, probably meroxene. Penetrating the mica, fine needles of apatite are often to be observed.

Another striking feature in these rocks is the presence of carbonate of lime in considerable quantity. In many cases they are so highly charged with calcite as to effervesce freely with acid. This mineral has completely replaced the original constituents of the rock, forming pseudomorphs, the shape of which gives some indication of the nature of the replaced mineral. Augite has doubtless been replaced in this way, and the shapes of some of the calcite pseudomorphs clearly point to olivine having been an original accessory constituent of these rocks. The felspar (orthoclase) is surprisingly small in quantity, being confined to small microlites and interstitial patches in the groundmass, but the latter is generally so obscured by calcite dust and stained by oxide of iron that even this can only be made out after dissolving away the carbonate of lime from the section with dilute acid. Chlorite is also present in patches and scattered fibres. In part this mineral is no doubt derived from the decomposition of the biotite, in part also from the augite. Magnetite is present in scattered granules.

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3. *Note on Phillips's Dyke, Ingleton.* *By* THOMAS TATE, *F.G.S.*

The author stated that visitors to Ingleborough could examine an interesting mica-trap, the only one of the numerous West Yorkshire dykes described by Phillips in his classical work ('Yorkshire Geology,' Part II., Mountain Limestone, p. 85, 1835).

Intrusive in Coniston calcareous shales, north of the Cravenfault, it projects as a nearly vertical dyke from the east bank of the Doe, three hundred yards above the Catleap waterfall, Storrs, Ingleton.

Macroscopically it is a flesh-coloured matrix, fine-grained, and of uniform texture, enclosing porphyritic crystal groups of somewhat larger felspar crystals surrounded by a framework of brown mica.

The microscopic sections (exhibited) reveal a holocrystalline ground mass, of which orthoclase, hornblende, and biotite are the chief components, the latter mineral alone presenting idiomorphic contours.

Two generations of felspar; small crystals of uniform size diffused through, and originally the main constituents of, the ground-mass; and larger crystals in glomero-porphyritic clusters, each enclosed by magnesian mica generated around it, repeat the peculiar structure seen in hand specimens. The rock is a Mica-syenite or Minette, the best preserved of all the West Yorkshire traps.

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4. *Sixth Report on the Volcanic Phenomena of Vesuvius.*—See Reports, p. 397.

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5. *On the Origin of the Saline Inclusions in the Crystalline Rocks of Dartmoor.* *By* A. R. Hunt, *M.A., F.G.S.*

The author stated that he had examined 24 sections of crystalline rocks and quartz veins connected with the granite of Dartmoor, and found them all to contain without exception fluid inclusions with cubic crystals. That the cubic crystals in the Dartmoor granites indicate, to some extent at least, chloride of sodium seems hardly open to doubt, as the inclusions are exactly like those figured by Dr. Sorby from Cornwall, which proved on analysis to contain that salt.

There are four classes of rock in which these saline inclusions occur, viz.:

(1) The ordinary porphyritic granite of Dartmoor.
(2) Eruptive veins of fine-grained granite traversing the main mass and the adjacent sedimentary rocks.
(3) Quartz-tourmaline-felspar veins of aqueous origin, also traversing the main mass and adjacent sedimentaries.
(4) Veins of pure quartz in the culm slates.

A quartz crystal about one-thirtieth of an inch in diameter in one of the aqueous veins contains six different sorts of inclusions, viz.:

(1) Irregular cavities with both cubic crystal and bubble.
(2) Irregular cavities with cubic crystal alone.
(3) Irregular cavities with bubble alone.

The same three varieties occur as negative hexagons, making six altogether.

The bubbles vary greatly in relative size and activity. In the case under discussion variation cannot be explained either on the hypothesis of original and secondary inclusions or on that of variation in weight of superincumbent strata by accumulation or denudation.

After consolidation the crystal was never crushed, nor was it plastic, nor was it permeated by fluids; but during growth it was subjected to rapid alternations of salt water and fresh, and to great changes of pressure.

Dynamic pressure by earth movements, and variation in the weight of superincumbent rocks, being negatived, there seems to be nothing to fall back upon to explain the variations of pressure except irregularly heated water in the vein itself.

Hot salt springs occur in Cornish mines, probably (as shown by the late Mr. J. A. Phillips) derived from the sea.

The phenomena of the Dartmoor veinstones can be explained on the hypothesis that sea-water gained access to highly heated granite during the epoch of their formation.

Sufficient heat would vaporise the brine and render possible the inclusion of fresh water in the form of compressed steam, in close juxtaposition with an inclusion of saturated brine previously entangled by the growing crystal. The occurrence of fresh water and brine inclusions close together must be explained somehow.

Any explanation relied on for the veinstones must also cover the case of the main mass of the granite, saturated as it seems to have been with salt.

Under extreme changes of temperature granite cracks throughout without much alteration in appearance, but a minutely cracked granite would suck in salt water like a sponge either under pressure or by capillary attraction.

From some cause or other the granite of Dartmoor has been cracked throughout, as evidenced by many of the porphyritic felspars. A rise of the isogeotherms, or plutonic action, of which latter there is abundant evidence in the elvans and granitic veins, are possible sources of the required heat.

The theory of the marine origin of the saline inclusions in the Dartmoor rocks seems to harmonise well with the view commonly entertained that the chlorine and chloride of sodium emitted by volcanoes are derived from the sea.[1]

In the case of volcanoes the presence of hydrogen and chlorine may be

[1] See *Characteristics of Volcanoes*, J. D. Dana, p. 8.

accounted for by the dissociation of the water and of the chloride of sodium by the intense heat,[1] and the combination of the two gases thus formed would result in the production of hydrochloric acid.

In the case of the cooler granites there is no question of dissociation and of gases, but of the entanglement of brine and steam at more moderate temperatures.

Thus the access of salt water to highly heated rocks seems to account for some of the more important gases emitted by lavas and of the more characteristic fluid inclusions caught up by granites.

An alternative theory, that the crystals of salt in the Dartmoor rocks 'had been formed from hydrochloric acid acting on the soda in the rocks,' does not seem to the author to account for the crystals in the quartz-veins of the culm slates, or to explain the complete permeation of the granite by the chloride of sodium. Moreover, the one theory accounts for the presence and origin of the hydrochloric acid as well as of the soda, whereas the other has to assume the previous existence of soda and the advent of hydrochloric acid from unknown quarters.

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6. *On the Strata forming the Base of the Silurian in North-East Montgomeryshire.* *By* J. BICKERTON MORGAN, *F.G.S.*

The area in which the rocks referred to in this communication occur is situate between the towns of Welshpool and Llanfyllin, on the North Wales border. These basal rocks, which were investigated by the author at the suggestion of Professor Lapworth, are first seen in Powis Castle Park, one mile to the south-west of the former place, where they come to the surface in the form of a small anticline, the southern limb of which furnishes the foundation upon which stands the ancient and picturesque structure of Powis Castle. From this point they take a north-easterly direction, and, passing through the upper, or western, portion of the town, are abruptly terminated at Red Bank by a north-east and south-west fault. Westward of the town they crop out in the neighbourhood of Frochas, and, striking thence through the folded strata north-eastward, they extend for several miles in the direction of Llansaintffraid.

The character of these basement rocks is, for the most part, that of a hard quartzose grit, the base of which, in places, takes the form of a coarse purple conglomerate, and which sometimes includes amongst its more siliceous constituents pebbles obtained from the underlying rocks, and occasionally contains green, earthy, concretionary patches. The grit-beds are sometimes sub-calcareous, and graduate upwards into fine-grained sandstones, the whole being characterised by possessing a deep red colour.

On sheet 60 N.E. of the Geological Survey Map these grits and sandstones are shown as Caradoc, and in both 'The Silurian System' and 'Siluria' Sir Roderick Murchison identifies them as belonging to the upper portion of his Caradoc sandstone. Although fossils are by no means abundant or generally distributed, sufficient palæontological evidence has been obtained from these beds to prove that they are of unquestionable May Hill age.

As these strata are followed from point to point in the district, they are found to repose transgressively upon different zones of the underlying Ordovician Rocks, so that in this area there is a distinct prolongation of the regional unconformity between the Ordovician and Silurian systems, an unconformity which can now be followed continuously from Llandeilo to Llanfyllin.

Above these red rocks comes a series of shales, mudstones, and sandstones, in which occur occasional courses of more calcareous matter, containing fossils of Lower Wenlock age.

The discovery of the May Hill age of these rocks will, therefore, necessitate a re-mapping of the district for the purpose of rectifying the boundary line at the base of the Silurian—a task the author hopes to complete in his leisure time.

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[1] See *Characteristics of Volcanoes*, J. D. Dana, p. 8.

7. *The Geology of the Long Mountain, on the Welsh Borders. By* W. W. Watts, *M.A., F.G.S.*

The author described the Silurian succession in a part of West Shropshire and East Montgomeryshire.

1. May Hill grit, sometimes conglomeratic, containing one richly fossiliferous band of limestone at Cefn, Buttington. This is traced from Cefn to the north end of the Breidden Hills, where it appears to thin out. It rests unconformably on various members of the Bala group, and at Cefn a small dyke of diabase is intruded along the junction line.

2. Purple and green shales with very rare fossils, chiefly entomostraca and small brachiopods.

3. Wenlock mudstones, earthy in the lower part, and more calcareous above, and containing *Cyrtograptus Linnarssoni*, *Monograptus Flemingii*, *M. dubius*, and *M. serra*. These beds appear to represent the upper part of the Wenlock shale and the Wenlock limestone.

4. Thin muddy shales with rare flaggy ribs, containing *Monograptus colonus*, *M. Nilssoni*, and *Cardiola interrupta*; these are the equivalent of the Lower Ludlow beds.

5. Hard thick flags, with occasional shales. *Monograptus Leintwardinensis*, *M. Salweyi*, *M. Roemeri*, the equivalent of the Aymestry limestone.

6. Thin fissile shales almost barren, but with *Cardiola*. These occupy the place of the Upper Ludlow Rocks. Above these beds comes an outlier of the Passage beds with *Lingula* and entomostraca.

The structure of the range is a large syncline with a steep dip on the north-west side, but this is complicated by several dip- and strike-faults and one or two small synclines.

The author acknowledged the great help rendered by Professor Lapworth in determining the graptolites.

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8. *Elbolton Cave Exploration. By the* Rev. Edward Jones.

Elbolton Cave lies at the foot of a small scar near the summit of Elbolton, a conical limestone hill near the village of Thorpe, about nine miles north of Skipton in Craven. Under the auspices of the Craven Naturalists' Association this cave is being explored. The present entrance is pit-like, and after a descent of 20 ft. we come to the level of the First Chamber, as seen before the exploration began. This chamber is from 30 to 40 feet long, and varies from 7 to 13 ft. in width. So far the workings have been confined to this chamber. During the summer of 1888 and the autumn of 1889 a great mass of material has been removed and examined. The level of the cave floor was painted on the walls, and this painted line marked off into divisions three feet apart on the north and south walls, and numbered in feet from a datum line at the cave mouth. These cave markings correspond with a plan of cave, in which the whole surface is divided into square feet. As the excavation proceeded the floor altered in shape, and other plans at 5 and 10 ft. deep from the surface line were made. The upper layer consisted of loose angular fragments of limestone rock. This we have termed the Upper Cave earth. It is of varying thickness, from 4 ft. at the entrance to the cave to 17 ft. at the west end. All the human remains have been found in this deposit, but as yet no implement or evidence of man beneath it. Beneath this Upper Cave earth we come to a layer of angular stones imbedded in a stiff clay. At the east end a floor of stalagmitic breccia lies between the two layers. The clay layer has not yet been pierced. At the west end we have now reached a depth of 32 ft. from the cave floor; 17 ft. of this is the loose upper cave earth, and the remainder clay and stalagmite. Both the upper and lower strata abound in remains. The upper is evidently Neolithic. No metal of any kind, either bronze or iron, has been found. Remains of a dozen men have come to hand, the greater part scattered amidst other bones, but some have been found *in situ* as buried. At 12 ft. S. from the datum a skeleton nearly complete was found; in a recess three feet further another was seen, and in the middle of the chamber a third was obtained. Two of these were in an upright sitting posture, the knees being bent close to the skull and the thigh bones still inserted in the sockets of the pelvis. The skeleton of the first was similarly bent, but the body had evidently been laid sloping, and not erect. All the skulls are similar in character, of the 'long-headed' type. The quantity of bones of other animals brought out of this layer is very great. The bones of horse, boar, *bos longifrons*, red deer, sheep, fox, dog or wolf, badger, wild cat, smaller carnivora and rodents, and four or five kinds of birds are numerous. All the larger bones other than the human have been broken; many split lengthwise, most likely by the cave men to obtain marrow.

That the cave was occupied by neolithic men as well as used as a burial place, is shown in the presence of charcoal and burnt peat, with calcined bones. At 18 ft. north side, depth 9 ft. 6 in., evidence of an actual hearth was seen; a quantity of fragments of neolithic pottery was found. All the pieces were coated with charcoal on the inside. Ornamentation varied. Pot boiler, made of rounded grits, with marks of fire, and pieces of Silurian slates that may have been used to sharpen their bone implements have been found. The absence of flints is remarkable. A variety of bone pins have been picked up: some may have been hair-pins, others bodkins, and one undoubtedly was used to ornament the pottery, as the indentation on some pieces is the exact mould of the bone instrument.

The bones found in the lower clay bed are different in character from those found in the upper layer. The human bones, together with animals associated with man, are not found in this layer; but in their place we have those of bears, alpine hares, foxes, and the reindeer. Most of the bears are Ursus ferox. Some await further determination, and may turn out to be those of the cave bear. The hares are specially abundant, more than one hundred individuals having been already obtained.

Much work remains yet to be done. We have not reached the rock floor of the chamber, nor determined the original entrance into the cave. The exposed face of unworked material is now 22 ft. in thickness, all of it full of animal remains. The funds at the disposal of our small local society for this exploration are nearly exhausted. Yet we think that it is very desirable that the exploration of this interesting little cave should be satisfactorily completed.

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9. *Physical Studies of an Ancient Estuary. By the* Rev. A. Irving, *D.Sc., F.G.S.*

Attention is drawn to some of the more important instances of the formation of new land by rivers which Lyell has discussed in his 'Principles,' a process aptly termed by the French geologists 'atterrissement.' The formation of Sunk Island in the Humber is especially referred to; a genuine island just raising its head above the waters in the time of Charles II., it had joined itself to the land and acquired an area of between 6,000 and 7,000 acres by the middle of the present century. Professor Green's discussion of the physical geology of estuarine areas in his 'Physical Geology' is referred to as involving a series of conditions, all of which are more or less represented in the physical history of the Bagshot Beds of the London Basin; the physical, the stratigraphical, and the palæontological lines of evidence concurring to point to such a gradual advance from strictly fluviatile conditions to those of a marine estuary as can only be explained by a slow subsidence with intermittent pauses of long duration, during which the relative levels of sea and land remained pretty stationary.

The definite results of the author's own work, which have been in part published, are then reviewed; the organic origin of the green colouring-matter of many of the beds, and of the glauconite, the part played by vegetation in the production of limonite and pyrites, the formation of nodules of ironstone, the occurrence of lignite, the false-bedding of the sands and their interlamination with thin seams of pure clay at certain horizons, the possible origin of pipe-clay, are all briefly discussed with reference to the London Bagshots. Reference is also made to the author's discovery of remains of freshwater Diatoms in some of these beds. Additional facts are brought forward tending to strengthen the author's view as to the lagoon-origin of the green earthy sands, and an attempt is made to assign its real value to such fossil evidence as they furnish.

With regard to the view lately reiterated by Messrs. Gardner, Keeping, & Monckton, as to the possible marine origin of the upper sands, it is shown that the evidence is quite compatible with the theory of their marine-estuarine origin, while many of the features they present on a closer study can hardly be explained in any other way. The author, however, agrees with those writers that there is no real necessity for postulating any considerable break in time between the two series, as has been done by the Geological Survey. The distribution of the pebble-beds is discussed, and shown to admit of a rational explanation in accordance with the author's view as to the history of the Bagshot series. The 'decalcification' hypothesis of the writers referred to is criticised, and the probable mode of genesis of the irony casts found in the Upper Sands pointed out.

Lastly, the time required for the formation of these few hundred feet of strata, as measured by their continental equivalents, is seen to harmonise with the exceedingly slow rate of deposition which a study of the evidence of their physical history reveals to us.

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10. *Sixteenth Report on the Circulation of Underground Waters.* See Reports, p. 352.

TUESDAY, SEPTEMBER 9.

The following Reports and Papers were read:—

1. *Eighth Report upon the Fossil Phyllopoda of the Palæozoic Rocks.* See Reports, p. 424.

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2. *Report on the Cretaceous Polyzoa.*—See Reports, p. 378.

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3. *Suggestions on Sites for Coal-search in the South-East of England.*[1] *By* W. WHITAKER, *F.R.S., F.G.S.*

The object of the note is to point out that there are sites, favourably placed for the search, where much of the work is already done, in borings for water, &c., and the following places are noted:—At St. Margarets, near Dover, Gault was reached 548 feet down; as the Secondary beds thin northward a further depth of 700 or 800 feet might be enough to show whether or not coal is present. At Chartham, near Canterbury, Gault was reached at the depth of 735 feet. At Chatham, a boring penetrated Gault to 943 feet, and then entered Oxford Clay for 22 feet, a trial on Government land, which ought certainly to be continued, as is further urged by the results of the Chattenden boring. Shoreham (Kent), in Lower Greensand at 475 feet. Bushey (Herts), in Gault at 700 feet. 200 feet more here might yield useful results. Loughton—apparently through the Gault at nearly 1,100 feet. Coombs, near Stowmarket, in Gault at 895 feet.

Other borings, that reach to below the Chalk, at Caterham, East Horsley, Saffron Walden, Norwich, and Holkham, are referred to.

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4. *Notes on the Bunter and Keuper Formation in the Country around Liverpool.* *By* G. H. MORTON, *F.G.S.*

The Bunter and Keuper formations forming the Trias are fully developed in the district. Leaving out of consideration the Red Marl, of which only the lower beds

[1] Published in full in *Geol. Mag.* dec. iii. vol. vii. pp. 514–516 (1890).

occur, these formations are thicker than anywhere else in England. The thickness of the subdivisions of both Bunter and Keuper have been determined with great accuracy in recent years, and it is desirable to record the results.

The following section shows the succession and relative thickness of each of the subdivisions as derived from railway sections and tunnels, borings for water and coal-pits:—

			Feet
Trias.	Keuper 800 feet.	Red marl	400
		Keuper sandstone . . .	400
	Bunter 1,950 feet.	Upper soft sandstone . .	550
		Upper pebble-beds . . .	400
		Lower pebble-beds . . .	600
		Lower soft sandstone . .	400
			2,750

Excavations and borings have been in constant progress for many years, so that every bed in the Trias has been perforated, and in most horizons many times in succession, and it is now possible to tell exactly the strata to expect at any given depth when once those at the surface are ascertained.

Microscopic Structure.—In the Trias, the sandstones forming the subdivisions present typical characters, though it often happens that some interstratified beds of a softer or harder nature occur, and differ from those forming the rest of the strata. In a series of beds of sandstone 2,350 feet in thickness, it is difficult to draw general conclusions of much value, but the microscopical examination of a great number of specimens from many horizons in the Trias around Liverpool shows that there are five normal types, although they run, more or less, into each other, as follows:—

1. Coarse-grained sandstone, composed of rounded and sub-angular grains of quartz, *above* $\frac{1}{100}$ of an inch in diameter.
2. Fine-grained sandstone, composed of rounded and sub-angular grains of quartz, *less* than $\frac{1}{100}$ of an inch in diameter.
3. Coarse-grained sandstone, containing a great number of large grains of quartz, $\frac{1}{25}$ and $\frac{1}{35}$ of an inch in diameter, like a minute conglomerate.
4. Coarse-grained sandstone, composed of rounded, sub-angular, and crystallised grains of quartz—the crystallised faces having been deposited on the original grains after the sandstone was formed.
5. Coarse-grained sandstone, or quartzite, originally formed of rounded and sub-angular grains which have been united, by the deposition of silica, into a hard rock after the formation of the sandstone.

The lower soft sandstone is largely composed of the Nos. 1 and 3, and the upper soft sandstone of No. 2. Both the lower and upper pebble-beds are made up of No. 4, while the Keuper is the most variable, and consists of the Nos. 1 and 4, but all subject to the occurrence of exceptional beds of sandstone.

Triassic Pebbles.—The pebbles that occur in the Bunter formation are all found in the lower pebble-beds, and are usually less than an inch across, and it is very seldom that any reach the diameter of six inches. They consist of white-veined quartz, and quartzite varying in colour from white and grey to dark-red and brown. Nearly all are of a rounded or oval form, perfectly smooth, and must have come from a great distance, and most probably from the Cambrian and Silurian rocks of central England or Scotland. Next in frequency, though relatively few, are rough pebbles and angular fragments of coarse felspathic grit, sandstone, and chert, resembling beds in the Cefn-y-Fedw sandstone, Millstone Grit, and Coal Measures within 20 miles from Liverpool. These are generally found singly, but occur in brecciated beds on the coast of Cheshire, and the fragments are the largest at Hilbre Point at the mouth of the Dee. According to Professor T. G. Bonney, F.R.S., the quartzite pebbles resemble those found in Staffordshire, and it seems a question whether such a variety could have been derived from central England, or whether they did not probably come from the west of Scotland and travel along the eastern side of the present North Channel into Lancashire and Cheshire.

The pebbles of the Keuper sandstone occur almost entirely about the base of the formation, but they are few in number and variety compared with those in the Bunter. They consist of vein-quartz and quartzite of various shades of light and dark-grey. They do not seem to have been derived from the Bunter, and it is not likely that it was exposed to denudation when the Keuper was deposited. Probably the pebbles came from the same source as those in the Bunter, when the supply had dwindled away and was almost limited to those of light-coloured quartzite.

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5. *Notes on the Morphology of the Cystidea.* *By* P. HERBERT CARPENTER, *D.Sc., F.R.S.*

In many Cystidea the plates enclosing the lower part of the body are as regularly arranged as in the cup of a Crinoid. Thus in *Caryocrinus*, which is a hexamerous form, the base is dicyclic. Resting on the stem are four infra-basals, two of which are double plates. Above and alternating with these are the six basals, and above them again is a ring of eight plates, six of which alternate with the basals and represent the radials of a Crinoid, while the other two, each resting upon a basal, are supplementary or interradial plates. *Hemicosmites* is another dicyclic and hexamerous form, but has three supplemental interradials. *Protocrinites* too seems to have a dicyclic and hexamerous base. A similar interpretation may be given of many pentamerous genera besides the well-known *Porocrinus*. Thus, in *Echinoencrinus* plates 1 to 4 of Edward Forbes's nomenclature are infra-basals, No. 3 being a double plate. The sub-ovarian series, Nos. 5 to 9, alternating with them, are basals, while Nos. 10 to 14, the centrolaterals, Forbes, are radials. Nos. 15 to 19, alternating with these, and called supra-ovarian by Forbes, are interradial, and are perhaps homologous with the deltoids of the Blastoidea. The construction of the calyx in *Apiocystis, Callocystis, Cystoblastus, Glyptocystis, Pseudocrinus*, and various other well-known genera, is essentially similar to this, while there are three or more tiers of alternating plates in *Homocystis, Lichenoides, Macrocystella*, and *Mimocystis*. In some genera the mouth was protected by five oral plates, that on the anal side being larger than its fellows, as in the Palæocrinoids. *Cyathocystis, Glyptosphæra, Sphæronis*, and *Pyrocystis* had five, while *Caryocrinus* had six, with the posterior one subcentral, as in the Camerata. Two of Barrande's figures of *Pyrocystis desideratus*, which are internal and external views of the same specimen, show the relation of these oral plates to the 'hydrophores palmés.' These structures were not at the dorsal pole, as supposed by a recent writer in 'Nature,' but they were rightly interpreted by Neumayr as the remains of subtegminal ambulacra. In those types without a genital pore the anal pyramid may have subserved generative functions, as in the recent starfish *Hymenaster*. The armoured forms of the Psolidæ among Holothurians, with their anal pyramid and oral plates, present many points of resemblance to the Cystidea. *Aristocystis* seems to have had a fourth opening near the peristome, which was possibly nephridial, and the similar position of the third opening in *Echinoencrinus* suggests that it, too, may have been nephridial rather than genital.

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6. *On the Sources of the River Aire.* *By* Professor SILVANUS P. THOMPSON, *D.Sc.*

The author proposed to explore the source of the river Aire by a method involving the use of fluorescent bodies, such as fluorescein or its soluble derivative, uranin. Very small quantities of this material give a visible coloration to the surface of the water. He had applied this substance to test whether the water of Malham Tarn, which sinks into the ground about half a mile after leaving the tarn, emerges at the reputed 'Aire-head' two miles below, or at Malham Cove one mile below. He incidentally noticed that there is a second water-sink, not marked as such on the Ordnance maps. In a preliminary experiment about $1\frac{1}{4}$ pounds of uranin were thrown into the recognised water-sink; but after a lapse of three hours nothing whatever had been seen at Aire-head and nothing distinctive at Malham Cove.

The author concludes that either there is a considerable body of underground water at some intermediate spot between the water-sink and the cove, or that the Airehead spring communicates with some water-sink—possibly the one he had noticed—other than that marked on the Ordnance Survey maps.

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7. *Report on the Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.*—See Reports, p. 428.

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8. *On the Discovery of a Jurassic Fish-Fauna in the Hawkesbury-Wianamatta Beds of New South Wales. By* A. SMITH WOODWARD, *F.G.S.*

A large collection of fossil fishes from the Hawkesbury-Wianamatta series of Talbralgar, New South Wales, has been forwarded to the author for examination by Messrs. C. S. Wilkinson and R. Etheridge, jun., of the Geological Survey of New South Wales. The final results will appear in a forthcoming memoir, to be published by that Survey; but the investigation has already proceeded so far as to justify the announcement of the discovery of a typically Jurassic fish-fauna in Australia. Fine examples of the Palæoniscid genus *Coccolepis* occur, and this has previously been met with only in the Lower Lias of Dorset, the Purbeck beds of Wilts, and the lithographic stone of Bavaria. A new fish, allied to *Semionotus*, but with thinner, much imbricating scales, is also conspicuous; and another new form, allied to the Dapedioids, is remarkable from the presence of typical rhombic ganoid scales in the front half of the trunk and deeply-overlapping cycloid scales over the whole of the caudal region. A *Leptolepis*-like fish, with a persistent notochord, seems to represent a third unknown generic type. Of *Leptolepis* itself there are many hundreds of individuals in a fine state of preservation. The fishes occur in a hard, ferruginous, fissile matrix, associated with well-preserv ed remains of plants.

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9. *Restorations of the Palæozoic Elasmobranch Genera* Pleuracanthus *and* Xenacanthus. *By* DR. ANTON FRITSCH. (*Communicated by* A. SMITH WOODWARD.)

The author forwarded for exhibition the series of plates illustrating the forthcoming part of his work on the fauna of the Lower Permian gas coal of Bohemia. These were devoted to *Pleuracanthus* and *Xenacanthus*, of which the examination of more than 200 specimens had enabled the author to attempt nearly complete restorations. The chief result of the investigation is that the three genera, *Orthacanthus*, *Pleuracanthus*, and *Xenacanthus*, are well characterised, and prove to be true Selachians, having the cranial cartilage simple, with no distinct tracts of ossification. The skull resembles that of *Hybodus* and the Opistharthri of Gill. There are seven branchial arches, as in *Heptanchus*. The median fins are embryonic in character, and the two anal (?) fins take the place of the lower part of the heterocercal caudal fin. The pectoral fin is most primitive in *Orthacanthus*, more advanced in *Xenacanthus*, and still more resembling that of recent sharks in *Pleuracanthus*. There is no pelvic arch. The claspers of the male closely resemble those of recent Elasmobranchs, and are formed by modified postaxial rays. Intercalaria are developed in the vertebral column, but the notochord is persistent.

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10. *On Fossil Fish of the West Riding Coal-field. By* J. W. DAVIS, *F.G.S.*

The first recorded discovery of fossil fish-remains in the West Riding was in 1833, when Professor Johnston of Durham, along with a number of local geologists, found the remains of a large fish in the Deep coal at Middleton (which afterwards served as the type of the genus Megalichthys when the late Professor Agassiz visited Leeds in 1834, after the meeting of the British Association at Edinburgh). Other fragmentary remains were found at Low Moor, near Bradford. In a paper read at a meeting of the Yorkshire Geological and Polytechnic Society in December 1839 Mr. T. Pridgin Teale was able to enumerate four genera of ganoid and seven genera of placoid fish-remains which had been discovered in this coal-field. They were: Megalichthys, Acanthodes, Platysomus, and Holoptychius; Gyracanthus, Hybodus (Ctenacanthus), Pleuracanthus, Helodus, Ctenoptychius, Ctenodus, and Diplodus. In 1845 Mr. Henry Denny was able to add Petalodus to the genera previously known, and gives the authority of Agassiz for the occurrence of Diplopteris, but where he had not been able to ascertain. He also mentions the large tail of *Cœlacanthus phillipsii* found in the Lower coal-measures near Halifax. Mr. Denny records the discovery of batrachian reptiles in the Belgian coal-field, and whilst stating that no examples had been found in this country, recommends that search be made for them. After this time little interest appears to have been taken in the subject until the discovery of a *bone-bed* in the Lower coal-measures. It occurs immediately above the Better-bed coal; it extends over an area of ten square miles, and has nowhere a greater thickness than half an inch. In a communication to the Geological Society of London in 1876 fourteen species of Ganoids and twenty-one species of Elasmobranchs were enumerated from this bed, several of them being new. Bones of Labyrinthodonts were identified by Professor Miall as those of Loxomma. At Tingley, five miles from Leeds, the Adwalton Cannel coal is worked, and associated with it a very large number of fish-remains have been found. These formed the subject of another paper read to the Geological Society, in which twenty-five species, several new, of fossil fish-remains are enumerated. The most abundant fish is *Cœlacanthus tingleyensis*, Davis, and it is no exaggeration to state that thousands of this species have been dug up. Besides the fish-remains already described and recorded, others await determination. These two beds have proved by far the most prolific, but fish-remains have been found on seven other horizons, including the Halifax Hard-bed coal, Black-bed coal (Low Moor), Silkstone coal, Middleton Main coal, Yard or Joan coal, and the Barnsley Thick coal. Altogether more than fifty species of fossil fishes have been discovered and recorded from the Yorkshire coal-field.

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11. *Fourth Report on the 'Manure' Gravels of Wexford.* See Reports, p. 410.

WEDNESDAY, SEPTEMBER 10.

The following Reports and Papers were read:—

1. *Report on the Registration of Type Specimens.*—See Reports, p. 339.

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2. *On Peat overlying a Lacustrine Deposit at Filey.*[1] *By the* Rev. E. Maule Cole, *M.A., F.G.S.*

Several of the numerous lacustrine deposits on the top of the boulder clay cliffs of Holderness are visible from the shore, and are shown by bands of freshwater marls, varying from 1 to 3 feet in thickness. Some, like that of Skipsea (in which remains of the Irish elk have been found), are accompanied by peat. Phillips noticed a lacustrine deposit at Filey, and described it as clay, with a small amount of peat, in all 4 feet thick. Since then the denudation of the cliff has shown a section in which the peat is 6 feet thick and nearly 60 yards in width. A report of the flora is expected from Mr. Cash, of Halifax. The author suggests

[1] Published *in extenso* in the *Naturalist*, January 1891.

that the rainfall which fed this and other lacustrine deposits came from higher ground to the east, as the course of all the streams from the Holderness and Filey boulder clay is westwards.

3. *On the Origin of Gold.* *By* Professor J. Logan Lobley, *F.G.S.*

After pointing out that it was not the origin of auriferous veins, but of the gold itself that was the subject of his paper, the author, from facts recently made known, showed that while geological evidence is against its igneous origin, all the gold of all the rocks may have been derived from aqueous deposition—that, in fact, all this gold may have been deposited by marine action in the same way as the materials of the aqueous rocks themselves have been. And, moreover, that our unaltered sedimentary rocks, even of Tertiary age, may contain an equal amount of gold in proportion to their bulk with that of those altered or metamorphosed Cambrian and Silurian rocks, which have hitherto been regarded as the earth's great treasures of the precious metal.

The knowledge now possessed of Secondary and Tertiary auriferous veins in California controverts the Plutonic as well as the Palæozoic hypothesis, and the discovery of gold in sea-water and of its precipitation by organic matter alters the position of the question from that it occupied in the days of Murchison and Forbes.

If gold was originally derived from Plutonic sources it ought to be found among volcanic products which come from the same deep-seated sources, and only differ from Plutonic rocks in being solidified under different conditions. But gold, although a most widely distributed metal, is almost, if not quite, unknown as a product of volcanic regions. This is strongly against its igneous origin, and consequently points to the gold of the Palæozoic auriferous veins being derived by removal from sedimentary rocks in which it had been originally deposited. This removal could be effected by chemical combination, solution, infiltration, and segregation. Since silica may combine with gold under heated conditions, and the silicate of gold so formed be soluble in hot water, as is also silica, gold in the form of silicate could be carried by water, heated by deep-seated conditions or by the neighbouring uprise of fused matter, from its original position, and be deposited in veins with silica itself, when subsequent segregation would separate the silica of the silicate of gold and leave it as free gold imbedded in quartz as it is now found.

The discovery by Sonstadt of nearly a grain of gold to the ton of sea-water shows that the sea has always held in solution an ample store to give to its sediments the amount of gold they are now found to contain, and Daintree's discovery of the power of organic matter to precipitate gold from a solution of the terchloride explains the deposition of gold from sea-water, since on the sea-bottoms there has always been a large amount of organic matter.

Though the gold so deposited would be in infinitesimal proportion to the mass of the marine mineral sediments, it would be aggregated by nuclei of metallic sulphides by which it would be retained until thermal conditions favoured its conversion to a soluble silicate. The sulphide of iron, or pyrites, is known to nearly always contain gold, and hence it is to be concluded that the gold of the sedimentary rocks which have not been subjected to the favouring conditions for its separation and preservation in quartz veins is now in the metallic sulphides these rocks contain. In such rocks as the Chalk and the London Clay, the amount of pyrites is very great, and the author concluded by giving a rough estimate of what may be the amount of the gold now in the surface-rocks of the south-east of England, from which it appears that these deposits may contain gold to the value of 100,000,000*l.* sterling.

4. *As to certain Alterations in the Surface-level of the Sea off the South Coast of England.* *By* R. G. M. Browne, *F.G.S.*

With reference to the alterations everywhere observable, which have taken place in the positions, relatively with each other, of the land and sea surfaces, the author suggests that the mode in which such alterations have occurred does not appear to have been very fully discussed; and he points out that it seems to have been assumed that there is no alternative between the two hypotheses, either that there has been a general lowering of the ocean all the world over, or that the land has been repeatedly moved upward or downward. He states that the alternative doctrine, inferable from a logical analysis of astronomical phenomena bearing upon the subject, does not appear to have been seriously considered, and he mentions that some actual evidences are available, showing that in relation to the land the surface-level of the sea has, within comparatively recent historic times, become altered in some localities without any simultaneous uprising or dilatation of the solid land. He proceeds to show that the alteration in the shore-line of the coast, whereby the old sea-ports of Winchelsea and Rye have become inland towns, has been accompanied by a gradually progressive reduction in the depth of the water off that coast; that the surface-contour of the land up the valleys debouching on to the flat or level between those towns plainly indicates that when the sea flowed in and out of those valleys, as it did prior to the time of its receding from the old coast line, now some distance inland, and extending from Winchelsea to Rye, its surface-level in that part of the English Channel was higher than it now is even at the times of highest high tides; that the absolutely undisturbed structure of the Hastings sand-deposit—of which that inland district consists—defies the supposition that the 'change of level' between the land and sea surfaces in that neighbourhood has arisen from the upheaval of the land, and further, that certain ancient documents now existing in the Town Hall of Rye—among others, a charter of King Richard I. (in 1194) and a document of King Henry III.'s time (1248)—plainly show that prior to those dates the sea had surrounded the town of Rye, and that by reason of that town being no longer insulated it was more open to the attack of enemies, rendering necessary the repair of its walls of defence. The author also points out that certain circumstances, incidentally mentioned by Leland, Jeake, and other old writers, afford further historic evidence to the same effect.

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5. *Notes on Volcanic Eruptions.* *By* THOMAS HART, *F.G.S.*

It seems to be an undoubted fact that water coming into contact with highly-heated rock is one of the most important requisites to produce and sustain a volcanic eruption.

The difficulty has been to explain how the passage of water in such considerable quantities is brought about.

The author thinks that we must look to some other explanation than a supply from ordinary percolation alone, and refers to the active volcanoes of the world being in close proximity to coast lines or in land areas surrounded by the sea, also in a more special degree in volcanic island groups.

In his account of the great eruption of Vesuvius in A.D. 79 Pliny the Younger says: 'There had been noticed many days before a trembling of the earth, but that night it was so violent that one thought that everything was being not merely moved, but absolutely overturned.'

The author suggests that the principle of the 'self-acting injector,' now generally used for supplying steam-engine boilers with water, comes into play during violent paroxysmal outbursts of volcanic activity, and is assisted by the *blast* afterwards produced by the conversion of water into steam.

In the construction of these injectors the elastic force of the steam in the boiler is utilised, not only to force water into the boiler itself, but when required to lift it ten to twenty feet in addition as in a pump.

Therefore, applying this principle to the great eruption of Vesuvius in A.D. 79, the impetuosity of the current from below would carry water from the Bay of Naples along with it through the fissures produced by the preceding earthquake.

The same principle will apply to all volcanic eruptions, the water being supplied either by percolation, the sea, or both combined.

SECTION D.—BIOLOGY.

PRESIDENT OF THE SECTION—Professor A. MILNES MARSHALL, M.A., M.D., D.Sc., F.R.S.

THURSDAY, SEPTEMBER 4.

The PRESIDENT delivered the following Address:—

As my theme for this morning's address I have selected the Development of Animals. I have made this choice from no desire to extol one particular branch of biological study at the expense of others, nor through failure to appreciate or at least admire the work done and the results achieved in recent years by those who are attacking the great problems of life from other sides and with other weapons.

My choice is determined by the necessity that is laid upon me, through the wide range of sciences whose encouragement and advancement are the peculiar privilege of this Section, to keep within reasonable limits the direction and scope of my remarks; and is confirmed by the thought that, in addressing those specially interested in and conversant with biological study, your President acts wisely in selecting as the subject-matter of his discourse some branch with which his own studies and inclinations have brought him into close relation.

Embryology, referred to by the greatest of naturalists as 'one of the most important subjects in the whole round of Natural History,' is still in its youth, but has of late years thriven so mightily that fear has been expressed lest it should absorb unduly the attention of zoologists, or even check the progress of science by diverting interest from other and equally important branches.

Nor is the reason of this phenomenal success hard to find. The actual study of the processes of development; the gradual building up of the embryo, and then of the young animal, within the egg; the fashioning of its various parts and organs; the devices for supplying it with food, and for ensuring that the respiratory and other interchanges are duly performed at all stages: all these are matters of absorbing interest. Add to these the extraordinary changes which may take place after leaving the egg, the conversion, for instance, of the aquatic gill-breathing tadpole—a true fish as regards all essential points of its anatomy—into a four-legged frog, devoid of tail, and breathing by lungs; or the history of the metamorphosis by which the sea-urchin is gradually built up within the body of its pelagic larva, or the butterfly derived from its grub. Add to these again the far wider interest aroused by comparing the life-histories of allied animals, or by tracing the mode of development of a complicated organ, *e g.* the eye or the brain, in the various animal groups, from its simplest commencement, through gradually increasing grades of efficiency, up to its most perfect form as seen in the highest animals. Consider this, and it becomes easy to understand the fascination which embryology exercises over those who study it.

But all this is of trifling moment compared with the great generalisation which tells us that the development of animals has a far higher meaning; that the several embryological stages and the order of their occurrence are no mere accidents, but are forced on an animal in accordance with a law, the determination of which ranks as one of the greatest achievements of biological science.

The doctrine of descent, or of Evolution, teaches us that as individual animals arise, not spontaneously, but by direct descent from pre-existing animals, so also is it with species, with families, and with larger groups of animals, and so also has it been for all time; that as the animals of succeeding generations are related together, so also are those of successive geologic periods; that all animals, living or that have lived, are united together by blood relationship of varying nearness or remoteness; and that every animal now in existence has a pedigree stretching back, not merely for ten or a hundred generations, but through all geologic time since the dawn of life on this globe.

The study of Development, in its turn, has revealed to us that each animal bears the mark of its ancestry, and is compelled to discover its parentage in its own development; that the phases through which an animal passes in its progress from the egg to the adult are no accidental freaks, no mere matters of developmental convenience, but represent more or less closely, in more or less modified manner, the successive ancestral stages through which the present condition has been acquired.

Evolution tells us that each animal has had a pedigree in the past. Embryology reveals to us this ancestry, because every animal in its own development repeats this history, climbs up its own genealogical tree.

Such is the Recapitulation Theory, hinted at by Agassiz, and suggested more directly in the writings of von Baer, but first clearly enunciated by Fritz Müller, and since elaborated by many, notably by Balfour and by Ernst Haeckel.

It is concerning this theory, which forms the basis of the science of Embryology, and which alone justifies the extraordinary attention this science has received, that I venture to address you this morning.

A few illustrations from different groups of animals will best explain the practical bearings of the theory, and the aid which it affords to the zoologist of to-day; while these will also serve to illustrate certain of the difficulties which have arisen in the attempt to interpret individual development by the light of past history—difficulties which I propose to consider at greater length.

A very simple example of recapitulation is afforded by the eyes of the sole, plaice, turbot, and their allies. These 'flat fish' have their bodies greatly compressed laterally; and the two surfaces, really the right and left sides of the animal, unlike, one being white, or nearly so, and the other coloured. The flat fish has two eyes, but these, in place of being situated, as in other fish, one on each side of the head, are both on the coloured side. The advantage to the fish is clear, for the natural position of rest of a flat fish is lying on the sea bottom, with the white surface downwards and the coloured one upwards. In such a position an eye situated on the white surface could be of no use to the fish, and might even become a source of danger, owing to its liability to injury from stones or other hard bodies on the sea bottom.

No one would maintain that flat fish were specially created as such. The totality of their organisation shows clearly enough that they are true fish, akin to others in which the eyes are symmetrically placed one on each side of the head, in the position they normally hold among vertebrates. We must therefore suppose that flat fish are descended from other fish in which the eyes are normally situated.

The Recapitulation Theory supplies a ready test. On employing it, *i.e.*, on studying the development of the flat fish, we obtain a conclusive answer. The young sole on leaving the egg is shaped just as any ordinary fish, and has the two eyes placed symmetrically on the two sides of the head. It is only after the young fish has reached some size, and has begun to approach the adult in shape, and to adopt its habit of resting on one side on the sea bottom, that the eye of the side on which it rests becomes shifted forwards, then rotated on to the top of the head, and finally twisted completely over to the opposite side.

The brain of a bird differs from that of other vertebrates in the position of the optic lobes, these being situated at the sides instead of on the dorsal surface. Development shows that this lateral position is a secondarily acquired one, for throughout all the earlier stages the optic lobes are, as in other vertebrates, on the dorsal surface, and only shift down to the sides shortly before the time of hatching.

Crabs differ markedly from their allies, the lobsters, in the small size and rudimentary condition of their abdomen or 'tail.' Development, however, affords abundant evidence of the descent of crabs from macrurous ancestors, for a young crab at what is termed the Megalopa stage has the abdomen as large as a lobster or prawn at the same stage.

Molluscs afford excellent illustrations of recapitulation. The typical gastropod has a large spirally-coiled shell; the limpet, however, has a large conical shell, which in the adult gives no sign of spiral twisting, although the structure of the animal shows clearly its affinity to forms with spiral shells. Development solves the riddle at once, telling us that in its early stages the limpet embryo has a spiral shell, which is lost on the formation, subsequently, of the conical shell of the adult.

Recapitulation is not confined to the higher groups of animals, and the Protozoa themselves yield most instructive examples. A very striking case is that of Orbitolites, one of the most complex of the porcellanous Foraminifera, in which each individual during its own growth and development passes through the series of stages by which the cyclical or discoidal type of shell was derived from the simpler spiral form.

In *Orbitolites tenuissima*, as Dr. Carpenter has shown,[1] 'the whole transition is actually presented during the successive stages of its growth. For it begins life as a Cornuspira, ... its shell forming a continuous spiral tube, with slight interruptions at the points at which its successive extensions commence; while its sarcodic body consists of a continuous coil with slight constrictions at intervals. The second stage consists in the opening out of its spire, and the division of its cavity at regular intervals by transverse septa, traversed by separate pores, exactly as in Peneroplis. The third stage is marked by the subdivision of the "peneropline" chambers into chamberlets, as in the early forms of Orbiculina. And the fourth consists in the exchange of the spiral for the cyclical plan of growth, which is characteristic of Orbitolites; a circular disc of progressively increasing diameter being formed by the addition of successive annular zones around the entire periphery.'

The shells both of Foraminifera and of Mollusca afford peculiarly instructive examples for the study of recapitulation. As growth of the shell is effected by the addition of new shelly matter to the part already existing, the older parts of the shell are retained, often unaltered, in the adult; and in favourable cases, as in *Orbitolites tenuissima*, all the stages of development can be determined by simple inspection of the adult shell.

It is important to remember that the Recapitulation Theory, if valid, must apply not merely in a general way to the development of the animal body, but must hold good with regard to the formation of each organ or system, and with regard to the later equally with the earlier phases of development.

Of individual organs, the brain of birds has been already cited. The formation of the vertebrate liver as a diverticulum from the alimentary canal, which is at first simple, but by the folding of its walls becomes greatly complicated, is another good example; as is also the development of the vomer in Amphibians as a series of toothed plates, equivalent morphologically to the placoid scales of fishes, which are at first separate, but later on fuse together and lose the greater number of their teeth.

Concerning recapitulation in the later phases of development and in the adult animal, the mode of renewal of the nails or of the epidermis generally is a good example, each cell commencing its existence in an indifferent form in the deeper layers of the epidermis, and gradually acquiring the adult peculiarities as it approaches the surface, through removal of the cells lying above it.

[1] W. B. Carpenter, 'On an Abyssal Type of the Genus Orbitolites,' *Phil. Trans.* 1883, part ii. p. 553.

The above examples, selected almost haphazard, will suffice to illustrate the Theory of Recapitulation.

The proof of the theory depends chiefly on its universal applicability to all animals, whether high or low in the zoological scale, and to all their parts and organs. It derives also strong support from the ready explanation which it gives of many otherwise unintelligible points.

Of these latter a familiar and most instructive instance is afforded by rudimentary organs, *i.e.*, structures which, like the outer digits of the horse's leg, or the intrinsic muscles of the ear of a man, are present in the adult in an incompletely developed form, and in a condition in which they can be of no use to their possessors; or else structures which are present in the embryo, but disappear completely before the adult condition is attained, for example, the teeth of whalebone whales, or the branchial clefts of all higher vertebrates.

Natural Selection explains the preservation of useful variations, but will not account for the formation and perpetuation of useless organs; and rudiments such as those mentioned above would be unintelligible but for Recapitulation, which solves the problem at once, showing that these organs, though now useless, must have been of functional value to the ancestors of their present possessors, and that their appearance in the ontogeny of existing forms is due to repetition of ancestral characters. Such rudimentary organs are, as Darwin pointed out, of larger relative or even absolute size in the embryo than in the adult, because the embryo represents the stage in the pedigree in which they were functionally active.

Rudimentary organs are extremely common, especially among the higher groups of animals, and their presence and significance are now well understood. Man himself affords numerous and excellent examples, not merely in his bodily structure, but by his speech, dress, and customs. For the silent letter *b* in the word 'doubt,' or the *w* of 'answer,' or the buttons on his elastic-side boots are as true examples of rudiments, unintelligible but for their past history, as are the ear muscles he possesses but cannot use, or the gill-clefts, which are functional in fishes and tadpoles, and are present, though useless, in the embryos of all higher vertebrates, which in their early stages the hare and the tortoise alike possess, and which are shared with them by cats and by kings.

Another consideration of the greatest importance arises from the study of the fossil remains of the animals that formerly inhabited the earth. It was the elder Agassiz who first directed attention to the remarkable agreement between the embryonic growth of animals and their palæontological history. He pointed out the resemblance between certain stages in the growth of young fish and their fossil representatives, and attempted to establish, with regard to fish, a correspondence between their palæontological sequence and the successive stages of embryonic development. He then extended his observations to other groups, and stated his conclusions in these words:[1] 'It may therefore be considered as a general fact, very likely to be more fully illustrated as investigations cover a wider ground, that the phases of development of all living animals correspond to the order of succession of their extinct representatives in past geological times.'

This point of view is of the utmost importance. If the development of an animal is really a repetition of its ancestral history, then it is clear that the agreement or parallelism which Agassiz insists on between the embryological and palæontological records must hold good. Owing to the attitude which Agassiz subsequently adopted with regard to the theory of Natural Selection, there is some fear of his services in this respect failing to receive full recognition, and it must not be forgotten that the sentence I have quoted was written prior to the clear enunciation of the Recapitulation Theory by Fritz Müller.

The imperfection of the geological record has been often referred to and lamented. It is very true that our museums afford us but fragmentary pictures of life in past ages; that the earliest volumes of the history are lost, and that of others but a few torn pages remain to us; but the later records are in far more satisfactory condition. The actual number of specimens accumulated from the more recent formations is prodigious; facilities for consulting them are far greater

[1] L. Agassiz, *Essay on Classification*, 1859, p. 115.

than they were; the international brotherhood of science is now fully established, and the fault will be ours if the material and opportunities now forthcoming are not rightly and fully utilised.

By judicious selection of groups in which long series of specimens can be obtained, and in which the hard skeletal parts, which alone can be suitably preserved as fossils, afford reliable indications of zoological affinity, it is possible to test directly this correspondence between palæontological and embryological histories, while in some instances a single lucky specimen will afford us, on a particular point, all the evidence we require.

Great progress has already been made in this direction, and the results obtained are of the most encouraging description.

By Alexander Agassiz a detailed comparison was made between the fossil series and the developmental stages of recent forms in the case of the Echinoids, a group peculiarly well adapted for such an investigation. The two records agree remarkably in many respects, more especially in the independent evidence they give as to the origin of the asymmetrical forms from more regular ancestors. The gradually increasing complication in some of the historic series is found to be repeated very closely in the development of their existing representatives; and with regard to the whole group, Agassiz concludes that,[1] 'comparing the embryonic development with the palæontological one, we find a remarkable similarity in both, and in a general way there seems to be a parallelism in the appearance of the fossil genera and the successive stages of the development of the Echini.'

Neumayr has followed similar lines, and between him and other authorities on the group there seems to be general agreement as to the parallelism between the embryological and palæontological records, not merely for Echini, but for other groups of Echinodermata as well.

The Tetrabranchiate Cephalopoda are an excellent group in which to study the problem, for though no opportunity has yet occurred for studying the embryology of the only surviving member of the group, the pearly nautilus, yet owing to the fact that growth of the shell is effected by addition of shelly matter to the part already present, and to the additions being made in such manner that the older part of the shell persists unaltered, it is possible, from examination of a single shell—and in the case of fossils the shells are the only part of which we have exact knowledge—to determine all the phases of its growth; just as in the shell of Orbitolites all the stages of development are manifest on inspection of an adult specimen.

In such a shell as Nautilus or Ammonites the central chamber is the oldest or first formed one, to which the remaining chambers are added in succession. If, therefore, the development of the shell is a repetition of ancestral history, the central chamber should represent the palæontologically oldest form, and the remaining chambers in succession forms of more and more recent origin. Ammonite shells present, more especially in their sutures, and in the markings and sculpturing of their surface, characters that are easily recognised, and readily preserved in fossils; and the group, consequently, is a very suitable one for investigation from this standpoint.

Würtenberger's admirable and well-known researches[2] have shown that in the Ammonites such a correspondence between historic and embryonic development does really exist; that, for example, in Aspidoceras the shape and markings of the shells in young specimens differ greatly from those of adults, and that the characters of the young shells are those of palæontologically older forms.

Another striking illustration of the correspondence between the palæontological and developmental records is afforded by the antlers of deer, in which the gradually increasing complication of the antler in successive years agrees singularly closely with the progressive increase in size and complexity shown by the fossil series from the Miocene age to recent times.

[1] A. Agassiz, *Palæontological and Embryological Development.* 'An Address before the American Association for the Advancement of Science.' 1880.

[2] L. Würtenberger, 'Studien über die Stammesgeschichte der Ammoniten. Ein geologischer Beweis für die Darwin'sche Theorie.' Leipzig, 1880.

Of cases where a single specimen has sufficed to prove the palæontological significance of a developmental character, Archæopteryx affords a typical example. In recent birds the metacarpals are firmly fused with one another and with the distal series of carpals; but in development the metacarpals are at first, and for some time, distinct. In Archæopteryx this distinctness is retained in the adult, showing that what is now an embryonic character in recent birds, was formerly an adult one.

Other examples might easily be quoted, but these will suffice to show that the relation between Palæontology and Embryology, first enunciated by Agassiz, and required by the Recapitulation Theory, does in reality exist. There is much yet to be done in this direction. A commencement, a most promising commencement, has been made, but as yet only a few groups have been seriously studied from this standpoint.

It is a great misfortune that palæontology is not more generally and more seriously studied by men versed in embryology, and that those who have so greatly advanced our knowledge of the early development of animals should so seldom have tested their conclusions as to the affinities of the groups they are concerned with by direct reference to the ancestors themselves, as known to us through their fossil remains.

I cannot but feel that, for instance, the determination of the affinities of fossil Mammalia, of which such an extraordinary number and variety of forms are now known to us, would be greatly facilitated by a thorough and exact knowledge of the development, and especially the later development, of the skeleton in their existing descendants, and I regard it as a reproach that such exact descriptions of the later stages of development should not exist even in the case of our commonest domestic animals.

The pedigree of the horse has attracted great attention, and has been worked at most assiduously, and we are now, largely owing to the labours of American palæontologists, able to refer to a series of fossil forms commencing in the lowest Eocene beds, and extending upwards to the most recent deposits, which show a complete gradation from a more generalised mammalian type to the highly specialised condition characteristic of the horse and its allies, and which may reasonably be regarded as indicating the actual line of descent of the horse. In this particular case, more frequently cited than any other, the evidence is entirely palæontological. The actual development of the horse has yet to be studied, and it is greatly to be desired that it should be undertaken speedily. Klever's[1] recent work on the development of the teeth in the horse may be referred to as showing that important and unexpected evidence is to be obtained in this way.

A brilliant exception to the statement just made as to the want of exact knowledge of the later development of the more highly organised animals is afforded by the splendid labours of Professor Kitchen Parker, whose recent death has deprived zoology of one of her most earnest and single-minded students, and zoologists, young and old alike, of a true and sincere friend. Professor Parker's extraordinarily minute and painstaking investigations into the development of the vertebrate skull rank among the most remarkable of zootomical achievements, and afford a rich mine of carefully recorded facts, the full value and bearing of which we are hardly yet able to appreciate.

If further evidence as to the value and importance of the Recapitulation Theory were needed, it would suffice to refer to the influence which it has had on the classification of the animal kingdom. Ascidians and Cirripedes may be quoted as important groups, the true affinities of which were first revealed by embryology; and in the case of parasitic animals the structural modifications of the adult are often so great that but for the evidence yielded by development their zoological position could not be determined. It is now indeed generally recognised that in doubtful cases embryology affords the safest of all clues, and that the zoological position of such forms can hardly be regarded as definitely established unless their development, as well as their adult anatomy, is ascertained.

[1] Klever, 'Zur Kenntniss der Morphogenese des Equidengebisses,' *Morphologisches Jahrbuch*, xv. 1889, p. 308.

It is owing to this Recapitulation Theory that Embryology has exercised so marked an influence on zoological speculation. Thus the formation in most, if not in all, animals of the nervous system and of the sense organs from the epidermal layer of the skin, acquired a new significance when it was recognised that this mode of development was to be regarded as a repetition of the primitive mode of formation of such organs; while the vertebral theory of the skull affords a good example of a view, once stoutly maintained, which received its death-blow through the failure of embryology to supply the evidence requisite in its behalf. The necessary limits of time and space forbid that I should attempt to refer to even the more important of the numerous recent discoveries in embryology, but mention may be very properly made here of Sedgwick's determination of the mode of development of the body cavity in Peripatus, a discovery which has thrown most welcome light on what was previously a great morphological puzzle.

We must now turn to another side of the question. Although it is undoubtedly true that development is to be regarded as a recapitulation of ancestral phases, and that the embryonic history of an animal presents to us a record of the race history, yet it is also an undoubted fact, recognised by all writers on embryology, that the record so obtained is neither a complete nor a straightforward one.

It is indeed a history, but a history of which entire chapters are lost, while in those that remain many pages are misplaced and others are so blurred as to be illegible; words, sentences, or entire paragraphs are omitted, and worse still, alterations or spurious additions have been freely introduced by later hands, and at times so cunningly as to defy detection.

Very slight consideration will show that development cannot in all cases be strictly a recapitulation of ancestral stages. It is well known that closely allied animals may differ markedly in their mode of development. The common frog is at first a tadpole, breathing by gills, a stage which is entirely omitted by the West Indian Hylodes. A crayfish, a lobster, and a prawn are allied animals, yet they leave the egg in totally different forms. Some developmental stages, as the pupa condition of insects, or the stage in the development of a dogfish in which the œsophagus is imperforate, cannot possibly be ancestral stages. Or again, a chick embryo of say the fourth day is clearly not an animal capable of independent existence, and therefore cannot correctly represent any ancestral condition, an objection which applies to the developmental history of many, perhaps of most animals.

Haeckel long ago urged the necessity of distinguishing in actual development between those characters which are really historical and inherited and those which are acquired or spurious additions to the record. The former he termed palingenetic or ancestral characters, the latter cenogenetic or acquired. The distinction is undoubtedly a true one, but an exceedingly difficult one to draw in practice. The causes which prevent development from being a strict recapitulation of ancestral characters, the mode in which these came about, and the influence which they respectively exert, are matters which are greatly exercising embryologists, and the attempt to determine which has as yet met with only partial success.

The most potent and the most widely spread of these disturbing causes arise from the necessity of supplying the embryo with nutriment. This acts in two ways. If the amount of nutritive matter within the egg is small, then the young animal must hatch early, and in a condition in which it is able to obtain food for itself. In such cases there is of necessity a long period of larval life, during which natural selection may act so as to introduce modifications of the ancestral history, spurious additions to the text.

If, on the other hand, the egg contain within itself a considerable quantity of nutrient matter, then the period of hatching can be postponed until this nutrient matter has been used up. The consequence is that the embryo hatches at a much later stage of its development, and if the amount of food material is sufficient may even leave the egg in the form of the parent. In such cases the earlier developmental phases are often greatly condensed and abbreviated; and as the embryo does not lead a free existence, and has no need to exert itself to obtain food, it commonly happens that these stages are passed through in a very modified form, the embryo being as in a four-day chick, in a condition in which it is clearly incapable of independent existence.

The nutrition of the embryo prior to hatching is most usually effected by granules of nutrient matter, known as food yolk, and embedded in the protoplasm of the egg itself; and it is on the relative abundance of these granules that the size of the egg chiefly depends.

Large size of eggs implies diminution of number of the eggs, and hence of the offspring; and it can be well understood that while some species derive advantage in the struggle for existence by producing the maximum number of young, to others it is of greater importance that the young on hatching should be of considerable size and strength, and able to begin the world on their own account. In other words, some animals may gain by producing a large number of small eggs, others by producing a smaller number of eggs of larger size—*i.e.*, provided with more food yolk.

The immediate effect of a large amount of food yolk is to mechanically retard the processes of development; the ultimate result is to greatly shorten the time occupied by development. This apparent paradox is readily explained. A small egg, such as that of Amphioxus, starts its development rapidly, and in about eighteen hours gives rise to a free swimming larva, capable of independent existence, with a digestive cavity and nervous system already formed; while a large egg, like that of the hen, hampered by the great mass of food yolk by which it is distended, has, in the same time, made but very slight progress.

From this time, however, other considerations begin to tell. Amphioxus has been able to make this rapid start owing to its relative freedom from food yolk. This freedom now becomes a retarding influence, for the larva, containing within itself but a very scanty supply of nutriment, must devote much of its energies to hunting for, and to digesting, its food, and hence its further development will proceed more slowly.

The chick embryo, on the other hand, has an abundant supply of food in the egg itself; it has no occasion to spend time searching for food, but can devote its whole energies to the further stages of its development. Hence, except in the earliest stages, the chick develops more rapidly than Amphioxus, and attains its adult form in a much shorter time.

The tendency of abundant food yolk to lead to shortening or abbreviation of the ancestral history, and even to the entire omission of important stages, is well known. The embryo of forms well provided with yolk takes short cuts in its development, jumps from branch to branch of its genealogical tree, instead of climbing steadily upwards.

Thus the little West Indian frog, Hylodes, produces eggs which contain a larger amount of food yolk than those of the common English frog. The young Hylodes is consequently enabled to pass through the tadpole stage before hatching, to attain the form of a frog before leaving the egg; and the tadpole stage is only imperfectly recapitulated, the formation of gills, for instance, being entirely omitted.

The influence of food yolk on the development of animals is closely analogous to that of capital in human undertakings. A new industry, for example that of pen-making, has often been started by a man working by hand and alone, making and selling his own wares; if he succeed in the struggle for existence, it soon becomes necessary for him to call in others to assist him, and to subdivide the work; hand labour is soon superseded by machines, involving further differentiation of labour; the earlier machines are replaced by more perfect and more costly ones; factories are built, agents engaged, and, in the end, a whole army of workpeople employed. In later times a man commencing business with very limited means will start at the same level as the original founder, and will have to work his way upwards through much the same stages, *i.e.*, will repeat the pedigree of the industry. The capitalist, on the other hand, is enabled, like Hylodes, to omit these earlier stages, and, after a brief period of incubation, to start business with large factories equipped with the most recent appliances, and with a complete staff of workpeople, *i.e.*, to spring into existence fully fledged.

There is no doubt that abundance of food yolk is a direct and very frequent cause of the omission of ancestral stages from individual development; but it must not be viewed as a sole cause. It is quite impossible that any animal, except perhaps in the lowest zoological groups, should repeat all the ancestral stages in the history of the race; the limits of time available for individual development will not permit this. There is a tendency in all animals towards condensation of the ancestral history, towards striking a direct path from the egg to the adult.

This tendency is best marked in the higher, the more complicated members of a group; *i.e.*, in those which have a longer and more tortuous pedigree; and though greatly strengthened by the presence of food yolk in the egg, is apparently not due to this in the first instance.

Thus the simpler forms of Orbitolites, as *O. tenuissima*, repeat in their development all the stages leading from a spiral to a cyclical shell; but in the more complicated species, as Dr. Carpenter has pointed out, there is a tendency towards precocious development of the adult characters, the earlier stages being hurried over in a modified form; while in the most complex examples, as in *O. complanata*, the earlier spiral stages may be entirely omitted, the shell acquiring almost from its earliest commencement the cyclical mode of growth. There is no question here of relative abundance of food yolk, but merely of early or precocious appearance of adult characters.

The question of the relations and influence of food yolk, involving as it does the larger or smaller size of the egg, is, however, merely a special side of the much wider question of the nutrition of the embryo, one of the most potent of the disturbing elements affecting development.

Speaking generally, we may say that large eggs are more often met with in the higher than the lower groups of animals. Birds and Reptiles are cases in point, and, if Mammals do not now produce large eggs, it is because a more direct and more efficient mode of nourishing the young by the placenta has been acquired by the higher forms, and has replaced the food yolk that was formerly present, and is now retained in quantity by Monotremes alone. Molluscs afford another good example, the eggs of Cephalopoda being of larger size than those of the less highly organised groups.

The large size of the eggs of Elasmobranchs, and perhaps that of Cephalopods also, may possibly be associated with the carnivorous habits of the animals; for it is of importance that forms which prey on other animals should hatch of considerable size and strength.

The influence of habitat must also be considered. It has long been noticed as a general rule that marine animals lay small eggs, while their fresh-water allies have eggs of much larger size. The eggs of the salmon or trout are much larger than those of the cod or herring; and the crayfish, though only a quarter the length of a lobster, lay eggs of actually larger size.

This larger size of the eggs of fresh-water forms appears to be dependent on the nature of the environment to which they are exposed. Considering the geological instability of the land as compared with the ocean, there can be no doubt that the fresh-water fauna is, speaking generally, derived from the marine fauna; and the great problem with regard to fresh-water life is to explain why it is that so many groups of animals which flourish abundantly in the sea should have failed to establish themselves in fresh water. Sponges and Cœlenterates abound in the sea, but their fresh-water representatives are extremely few in number; Echinoderms are exclusively marine: there are no fresh-water Cephalopods, and no Ascidians; and of the smaller groups of Worms, Molluscs, and Crustaceans, there are many that do not occur in fresh water.

Direct experiment has shown that in many cases this distribution is not due to inability of the adult animals to live in fresh water; and the real explanation appears to be that the early larval stages are unable to establish themselves under such conditions. This interesting suggestion, which has been worked out in detail by Professor Sollas,[1] undoubtedly affords an important clue. To establish itself

[1] W. J. Sollas, 'On the Origin of Freshwater Faunas,' *Scientific Transactions of the Royal Dublin Society*, vol. iii. ser. 11, 1886.

permanently in fresh water an animal must either be fixed, or else be strong enough to withstand and make headway against the currents of the streams or rivers it inhabits, for otherwise it will in the long run be swept out to sea, and this consideration applies to larval forms equally with adults.

The majority of marine Invertebrates leave the egg as minute ciliated larvæ: and such larvæ are quite incapable of holding their own in currents of any strength. Hence, it is only forms which have got rid of the free swimming ciliated larval stage, and which leave the egg of considerable size and strength, that can establish themselves as fresh-water animals. This is effected most readily by the acquisition of food yolk—hence the large size of the eggs of fresh-water animals—and is often supplemented, as Sollas has shown, by special protective devices of a most interesting nature. For this reason fresh-water forms are not so well adapted as their marine allies for the study of ancestral history as revealed in larval or embryonic development.

Before leaving the question of food yolk, reference must be made to the proposal of the brothers Sarasin, to regard the yolk cells as forming a distinct embryonic layer, the lecithoblast,[1] distinct from the blastoderm. I do not desire to speak dogmatically on a point the full bearings of which are not yet apparent, but I venture to think that this suggestion will not commend itself to embryologists. The distinction between the yolk granules and the cells in which they are embedded is a real and fundamental one; but I see no reason for regarding the yolk cells as other than originally functional endoderm cells in which yolk granules have accumulated to such an extent that they have in extreme cases become devoted solely to the storing of food for the embryo.[2]

Of all the causes tending to modify development, tending to obscure or falsify the ancestral record, food yolk is the most frequent and the most important; its position in the egg determines the mode of segmentation; and its relative abundance affects profoundly the entire embryonic history, and decides at what particular stage, and of what size and form, the embryo shall hatch.

The loss of food yolk is another disturbing element, the full influence of which is as yet imperfectly understood, but the possibility of which must be always kept in mind. It is best known in the case of mammals, where it has led to apparent, though very deceptive, simplification of development; and it will probably not be until the embryology of the large-yolked monotremes is at length described, that we shall fully understand the formation of the germinal layers in the higher placental mammals.

Amongst invertebrates we know but little as yet concerning the effects of loss of food yolk. It has been suggested that the extraordinary nature of the segmentation of the egg of *Peripatus capensis*, made known to us through Mr. Sedgwick's admirable researches, may be due to loss of food yolk; a suggestion which receives support from the long duration of uterine development in this case.

Our knowledge is very imperfect as to the ease with which food yolk may be acquired or lost; but until our information is more precise on this point, it seems unwise to lay much stress on suggested pedigrees which involve great and frequent alternations in the amount of food yolk present.

Of causes other than food yolk, or only indirectly connected with it, which tend to falsify the ancestral history, many are now known, but time will only permit me to notice the more important. These are distortion, whether in time or space; sudden or violent metamorphosis; a series of modifications, due chiefly to mechanical causes, and which may be spoken of as developmental conveniences; the important question of variability in development; and finally the great problem of degeneration.

Concerning distortions in time, all embryologists have noticed the tendency to anticipation or precocious development of characters which really belong to a later

[1] P. and F. Sarasin, *Ergebnisse naturwissenschaftlicher Forschungen auf Ceylon.* Bd. ii. Heft iii. 1889.

[2] *Cf.* E. B. Wilson, 'The Development of Renilla,' *Phil. Trans.* 1883, p. 755.

stage in the pedigree. The early attainment of the cyclical form in the shell of *Orbitolites complanata* is a case in point; and Würtenberger has specially noticed this tendency in Ammonites. Many early larvæ show it markedly, the explanation in this case being that it is essential for them to hatch in a condition capable of independent existence, *i.e.*, capable, at any rate, of obtaining and digesting their own food.

Anachronisms, or actual reversal of the historical order of development of organs or parts, occur frequently. Thus the joint surfaces of bones acquire their characteristic curvatures before movement of one part on another is effected, and before even the joint cavities are formed.

Another good example is afforded by the development of the mesenterial filaments in Alcyonarians. Wilson has shown in the case of Renilla that in the development of an embryo from the egg the six endodermal filaments appear first, and the two long ectodermal filaments at a later period; but that in the formation of a bud this order of development is reversed, the ectodermal filaments being the first formed. He suggests, in explanation, that as the endodermal filaments are the digestive organs, it is of primary importance to the free embryo that they should be formed quickly. The long ectodermal filaments are chiefly concerned with maintaining currents of water through the colony; in bud-development they appear before the endodermal filaments, because they enable the bud during its early stages to draw nutrient matter from the body fluid of the parent; while the endodermal filaments cannot come into use until the bud has acquired both mouth and tentacles.

The completion of the ventricular septum in the heart of higher vertebrates before the auricular septum is a well-known anachronism, and every embryologist could readily furnish many other cases.

A curious instance is afforded by the development of the teeth in mammals, if recent suggestions as to the origin of the milk dentition are confirmed, and the milk dentition prove to be a more recent acquisition than the permanent one.[1]

But the most important cases in reference to distortion in time concern the reproductive organs. If development were a strict and correct recapitulation of ancestral history, then each stage would possess reproductive organs in a mature condition. This is not the case, and it is clearly of the greatest importance that it should not be. It is true that the first commencement of the reproductive organs may occur at a very early larval stage, or even that the very first step in development may be a division of the egg into somatic and reproductive cells; and it is possible that, as maintained by Weismann, this latter condition is a primitive one. Still, even in these cases the reproductive organs merely commence their development at these early stages, and do not become functional until the animal is adult.

Exceptionally in certain animals, and as a normal occurrence in others, precocious maturation of the reproductive organs takes place, and a larval form becomes capable of sexual reproduction. This may lead to arrest of development, either at a late larval period as in the Axolotl, or at successively earlier and earlier stages, as in the gonophores of the Hydromedusæ, until finally the extreme condition seen in Hydra is produced.

We do not know the causes that determine the period, whether late or early, at which the reproductive organs ripen, but the question is one of great interest and importance and deserves careful attention. The suggestion has been made that entire groups of animals, such as the Mesozoa, are merely larvæ, arrested through such precocious acquiring of reproductive power, and it is conceivable that this may be the case. Mesozoa are a puzzling group in which the life history, though known with tolerable completeness, has as yet given us no reliable clue concerning their affinities to other animals, a tantalising distinction that is shared with them by Rotifers and Polyzoa.

[1] *Cf.* Thomas Oldfield, 'On the Homologies and Succession of the Teeth in the Dasyuridæ, with an attempt to trace the history of the evolution of the Mammalian teeth in general,' *Phil. Trans.* 1887.

Distortion of a curious kind is seen in cases of abrupt metamorphosis, where, as in the case of many Echinoderms, of Phoronis, and of the metabolic insects, the larva and the adult differ greatly in form, habits, mode of life, and very usually in the nature of their food and the mode of obtaining it; and the transition from one stage to the other is not a gradual but an abrupt one, at any rate so far as external characters are concerned.

Sudden changes of this kind, as from the free swimming Pluteus to the creeping Echinus, or from the sluggish leaf-eating caterpillar to the dainty butterfly, cannot possibly be recapitulatory, for even if small jumps are permissible in nature, there is no room for bounds forward of this magnitude. Cases of abrupt metamorphosis may always be viewed as due to secondary modifications, and rarely, if ever, have any significance beyond the particular group of animals concerned. For example, a Pluteus larva may be recognised as belonging to the group of Echinoidea before the adult urchin has commenced to be formed within it, and the Lepidopteran caterpillar is already an unmistakable insect. Hence, for the explanation of the metamorphoses in these cases it is useless to look outside the groups of Echinoidea and Insecta respectively.

Abrupt metamorphosis is always associated with great change in external form and appearance, and in mode of life, and very usually in mode of nutrition. A gradual transition in such cases is inadmissible, because in the intermediate stages the animal would be adapted to neither the larval nor the adult condition; a gradual conversion of the biting mouth parts of the caterpillar to the sucking proboscis of a moth would inevitably lead to starvation. The difficulty is evaded by retaining the external form and habits of one particular stage for an unduly long period, so that the relations of the animal to the surrounding environment remain unchanged, while internally preparations for the later stages are in progress. Cinderella and the princess are equally possible entities, each being well adapted to her environment. The exigencies of the situation do not permit, however, of a gradual change from one to the other: the transformation, at least as regards external appearance, must be abrupt.

Kleinenberg has recently directed attention to cases in which the larval and adult organs develop independently; the larval nervous system, for instance, aborting completely and forming no part of that of the adult. I am not sure that I fully understand Kleinenberg's argument, but it seems very possible that such cases, which are probably far more numerous than is yet admitted, may be due to what may be termed the telescoping of ancestral stages one within another, which takes place in actual development, and may accordingly be grouped under the head of developmental convenience. Undue prolongation of an early ancestral stage, as in cases of abrupt metamorphosis, must involve modification, especially in the muscular and nervous systems; in such cases a telescoping of ancestral stages takes place as we have seen, the adult being developed within the larva. Such telescoping must distort the recapitulatory history, and as the shape of the larva and adult may differ widely, an independent origin of organs, especially the muscular and nervous systems, may be acquired secondarily.

The stage in the development of Squilla, in which the three posterior maxillipedes disappear completely, to reappear at a later stage in a totally different form, is not to be interpreted as meaning that the adult maxillipedes are entirely new structures unconnected historically with those of the larva. Neither is the annual shedding of the antlers of deer to be regarded as the repetition of an ancestral hornless condition intercalated historically between successive stages provided with antlers. In both cases the explanation is afforded by convenience, whether of the embryo or adult.

Many embryological modifications or distortions may be attributed to mechanical causes, and may fairly be considered under the head of developmental conveniences.

The amnion of higher vertebrates is a case in point, and is probably rightly explained as due in the first instance to sinking or depression of the embryo into the yolk, in order to avoid distortion through pressure against a hard unyielding eggshell. A similar device is employed, presumably for the same reason, in the early development of many insect embryos; and the depression of the Tænia head within the cyst is a phenomenon of very similar nature.

Restriction of the space within which development occurs often causes displacement or distortion of organs whose growth, restricted in its normal direction, takes place along the lines of least resistance. The telescoping of the limbs and other organs within the body of an insect larva is a simple case of such distortion; and a more complicated example, closely comparable in many ways to the invagination of the Tænia head, is afforded by the remarkable inversion of the germinal layers in Rodents, first described by Bischoff in the Guinea pig, and long believed to be peculiar to that animal, but subsequently and simultaneously discovered by three independent observers, Kupffer, Selenka, and Fraser, to occur in varying degrees in rats, mice, and in other rodents.

One of the most recent attempts to explain developmental peculiarities as due to mechanical causes is Mr. Dendy's suggestion with regard to the pseudogastrula stage in the development of the calcareous sponges. It is well known that while the larva is in the amphiblastula stage, and still embedded in the tissues of the parent, the granular cells become invaginated within the ciliated cells, giving rise to the pseudogastrula stage. At a slightly later stage, when the larva becomes free, the invaginated granular cells become again everted, and the larva spherical in shape; while still later invagination occurs once more, the ciliated cells being this time invaginated within the granular cells. The significance of the pseudogastrula stage has hitherto been undetermined, but Mr. Dendy points out that the larva always occupies a definite position with reference to the parental tissues; that the ciliated half of the larva is covered by a soft and yielding wall, while the opposite half, composed of the granular cells, is covered by a layer stiffened with rigid spicules; and his observations on the growth of the larva lead him to think that the pseudogastrula stage is brought about mechanically by flattening of the granular cells through pressure against this rigid wall of spicules.

Embryology supplies us with many unsolved problems, and it is not to be wondered at that this should be the case. Some of these may fairly be spoken of as mere curiosities of development, while others are clearly of greater moment. I do not propose to catalogue these, but will merely mention two or three which I happen to have recently run my head against and remember vividly.

The solid condition of the œsophagus in Elasmobranch embryos, first noticed by Balfour, is a very curious point. The œsophagus has at first a well-developed lumen, like the rest of the alimentary canal; but at an early period, stage K of Balfour's nomenclature, the part of the œsophagus overlying the heart, and immediately behind the branchial region, becomes solid, and remains solid for a long time, the exact date of reappearance of the lumen not being yet ascertained.

Mr. Bles and myself have recently noticed that a similar solidification of the œsophagus occurs in tadpoles of the common frog. In young free swimming tadpoles the œsophagus is perforate, but in tadpoles of about 7½ mm. length it becomes solid and remains so until a length of about 10½ mm. has been attained. The solidification occurs at a stage closely corresponding with that in which it first appears in the dogfish, and a curious point about it is that in the frog the œsophagus becomes solid just before the mouth opening is formed, and remains solid for some little time after this important event.

This closing of the œsophagus clearly cannot be recapitulation, but the fact that it occurs at corresponding periods in the frog and dogfish suggests that it may possibly, as Balfour hinted, 'turn out to have some unsuspected morphological bearing.'

Another developmental curiosity is the duplication of the gill slits by growth downwards of tongues from their dorsal margins; a duplication which is described as occurring in Amphioxus and in Balanoglossus, but in no other animal; and the occurrence of which, in apparently closely similar fashion, is one of the strongest arguments in favour of a real affinity between these two forms. It is hardly possible that such a modification should have been acquired independently twice over.

A much more litigious question is the significance of the neurenteric canal of vertebrates, that curious tubular communication between the central canal of the nervous system and the hinder end of the alimentary canal that is conspicuously present in the embryos of lower vertebrates, and retained in a more or less disguised condition in the higher groups as well.

The neurenteric canal was discovered by that famous embryologist Kowalevsky in Ascidians and in Amphioxus. He drew special attention to the occurrence of a stage in both Ascidians and in Amphioxus in which the larva is free swimming and in which the sole communication between the alimentary cavity and the exterior is through the neurenteric canal and the central canal of the nervous system; and suggested[1] that animals may have existed or may still exist in which the nerve tube fulfilled a non-nervous function, and possibly acted as part of the alimentary canal; a suggestion that has recently been revived in a somewhat extravagant form.

A passage of food particles into the alimentary cavity through the neural tube has not yet been seen, and probably does not occur, as the larva still possesses sufficient food yolk to carry it on in its development. It is therefore permissible to hold that the neurenteric canal may be a mere embryological device, and devoid of any deep morphological significance.

The question of variation in development is one of very great importance, and has perhaps not yet received the attention it deserves. We are in some danger of assuming tacitly that the mode of development of allied animals will necessarily agree in all important respects or even in details, and that if the development of one member of a group be known, that of the others may be assumed to be similar. The more recent progress of embryology is showing us that such inferences are not safe, and that in allied genera or species, or even in different individuals of the same species, variations of development may occur affecting important organs and at almost any stage in their formation.

Great individual variations in the earliest processes of development, *i.e.*, the segmentation of the egg, have been described by different writers.

In Renilla, Wilson found an extraordinary range of variation in the segmentation of eggs from which apparently identical embryos were produced. In some cases the egg divided into two in the normal manner; in other cases it divided at once into eight, sixteen, or thirty-two segments, which in different specimens were approximately equal or markedly unequal in size. Sometimes a preliminary change of form occurred without any further result, the egg returning to its spherical shape, and pausing for a time before recommencing the attempt to segment. Segmentation sometimes commenced at one pole, as in telolecithal eggs, with the formation of four or five small segments, the rest of the egg breaking up later, either simultaneously or progressively, into segments about equal in size to those first formed: while lastly, in some instances segmentation was very irregular, following no apparent law.

It is noteworthy that the variability in the case of Renilla is apparently confined to the earliest stages, for whatever the mode of segmentation, the embryos in their later stages were indistinguishable from one another.

Similar modifications in the segmentation of the egg have been described in the oyster by Brooks, in Anodon and other Mollusca, in Hydra, and in Lumbricus, in which last Wilson has recently shown that marked differences occur in the eggs even of the same individual animal. In the different species of Peripatus there appear also to be considerable variations in the details of segmentation.

In the early embryonic stages after the completion of segmentation very considerable variation may occur in allied species or genera. Among Cœlenterates for instance the mode of formation of the hypoblast presents most perplexing modifications: it may arise as a true gastrula invagination; as cells budded off from one pole of the blastula into its cavity; as cells budded off from various parts of the wall of the blastula; by delamination or actual division of each cell of the blastula wall; or it may be present from the start as a solid mass of cells enclosed by the

[1] A. Kowalevsky, 'Weitere Studien über die Entwickelungs-Geschichte des Amphioxus lanceolatus; *Archiv für mikroskopische Anatomie*, Bd. xiii. 1877, p. 201.

epiblast cells. It is in connection with these variations that controversy has arisen as to the primitive mode of development of the gastrula, a point to which I shall return later on.

Among the higher Metazoa or Cœlomata the extraordinary modifications in the position and in every conceivable detail of formation of the mesoblast in different and often in closely allied forms have given rise to ardent discussion, and have led to the proposal of theory after theory, each rejected in turn as only affording a partial explanation, and now culminating in Kleinenberg's protest against the use of the term mesoblast at all, at any rate in a sense implying any possibility of comparison with the primary layers, epiblast and hypoblast, of Cœlenterata.

This is not the place to attempt to decide so difficult and technical a point, even were I capable of so doing, but we may well take warning from this extraordinary diversity of development, the full extent of which I believe we as yet realise most imperfectly, that in our attempts to reconstruct ancestral history from ontogenetic development we have taken in hand no light task. To reconstruct Latin from modern European languages would in comparison be but child's play.

Of the readiness with which special developmental characters are acquired by allied animals the brothers Sarasin[1] have given us evidence in the extraordinary modifications presented by the embryonic and larval respiratory organs of Amphibians.

Confining ourselves to those forms which do not lay their eggs in water, and in which consequently development takes place within the egg, we find that Ichthyophis and Salamandra have three pairs of specially modified external gills. Nototrema has two pairs; Alytes and Typhlonectes have only a single pair, which in the latter genus take the form of enormous leaf-like outgrowths from the sides of the neck. In Hylodes and Pipa there are no gills, the tail acting as the larval respiratory organ; and in *Rana opisthodon*, according to Boulenger, larval respiration is effected by nine pairs of folds of the skin of the ventral surface of the body.

Most of these extraordinarily diversified organs are clearly secondarily acquired structures; it is possible that they all are, and that external gills, as was suggested by Balfour for Elasmobranchs, are to be regarded as embryonal respiratory organs acquired by the larvæ and of no ancestral value. The point, however, cannot be considered settled, for on this view the external gills of Elasmobranchs and Amphibians would be independently acquired and not homologous structures, a view contradicted by the close agreement in their relations in the two groups, as well as by the absence of any real break between external and internal gills in Amphibians.

It is well known that the frog and the newt differ greatly in important points of their development. The two-layered condition of the epiblast in the frog is a marked point of difference, which involves further changes in the mode of formation of the nervous system and sense organs. The kidneys and their ducts differ considerably in their development in the two forms, as do also the bloodvessels.

Concerning the early development of the bloodvessels, there are considerable differences even between allied species of frogs. In *Rana esculenta* Maurer finds that there is at first in each branchial arch a single vessel or aortic arch, running directly from the heart to the aorta: from the cardiac end of this aortic arch a vessel grows out into the gill as the afferent branchial vessel, the original aortic arch losing its connection with the heart, and becoming the efferent branchial vessel. Afferent and efferent branchial vessels become connected by capillaries in the gill, and the course of the circulation, so long as gill-breathing is maintained, is from the heart through the truncus arteriosus to the afferent branchial vessel, then through the gill capillaries to the efferent branchial vessel, and then on to the aorta. When the pulmonary circulation is thoroughly established the branchial circulation is cut off by the efferent vessel reacquiring its connection with the heart, when the blood naturally takes the direct passage along it to the aorta, and so escapes the gill capillaries.

In *Rana temporaria* the mode of development is very different: the afferent and

[1] P. and F. Sarasin, *Ergebnisse naturwissenschaftlicher Forschungen auf Ceylon*, vol. ii. chap. i. pp. 24-38.

efferent vessels arise in each arch independently and almost simultaneously: the afferent vessel soon acquires connection with the heart; but, unlike *R. esculenta*, the efferent vessel has no connection with the heart until the gills are about to atrophy.

In other words, the continuous aortic arch, from heart to aorta, is present in *R. esculenta* prior to the development of the gills: it becomes interrupted while the gills are in functional use, but is re-established when these begin to atrophy. In *R. temporaria*, on the other hand, there is no continuous aortic arch until the gills begin to atrophy.

The difference is an important one, for it is a matter of considerable morphological interest to determine whether the continuous aortic arch is primitive for vertebrates: *i.e.*, whether it existed prior to the development of gills. This point could be practically settled if we could decide which of the two frogs, *R. esculenta* and *R. temporaria*, has most correctly preserved its ancestral history in this respect.

About this there can be little doubt. The development of the vessels in the newts, a less modified group than the frogs, agrees with that of *R. esculenta*, and interesting confirmation is afforded by a single aberrant specimen of *R. temporaria*, in which Mr. Bles and myself found the vessels developing after the type of *R. esculenta*, *i.e.*, in which a complete aortic arch was present before the gills were formed.

We are therefore justified in concluding that, as regards the development of the branchial bloodvessels, *R. esculenta* has retained a primitive ancestral character which is lost in *R. temporaria*, and it is interesting to note that were our knowledge of the development of amphibians confined to the common frog, the most likely form to be studied, we should, in all probability, have been led to wrong conclusions concerning the ancestral condition of the bloodvessels in a point of considerable importance.

A matter which at present is attracting much attention is the question of degeneration.

Natural selection, though consistent with and capable of leading to steady upward progress and improvement, by no means involves such progress as a necessary consequence. All it says is that those animals will, in each generation, have the best chance of survival which are most in harmony with their environment, and such animals will not necessarily be those which are ideally the best or most perfect.

If you go into a shop to purchase an umbrella the one you select is by no means necessarily that which most nearly approaches ideal perfection, but the one which best hits off the mean between your idea of what an umbrella should be and the amount of money you are prepared to give for it: the one, in fact, that is on the whole best suited to the circumstances of the case or the environment for the time being. It might well happen that you had a violent antipathy to a crooked handle, or else were determined to have a catch of a particular kind to secure the ribs, and this might lead to the selection, *i.e.*, the survival, of an article that in other and even in more important respects was manifestly inferior to the average.

So is it also with animals: the survival of a form that is ideally inferior is very possible. To animals living in profound darkness the possession of eyes is of no advantage, and forms devoid of eyes would not merely lose nothing thereby, but would actually gain, inasmuch as they would escape the dangers that might arise from injury to a delicate and complicated organ. In extreme cases, as in animals leading a parasitic existence, the conditions of life may be such as to render locomotor, digestive, sensory, and other organs entirely useless; and in such cases those forms will be best in harmony with their surroundings which avoid the waste of energy resulting from the formation and maintenance of these organs.

Animals which have in this way fallen from the high estate of their forefathers, which have lost organs or systems which their progenitors possessed, are commonly called degenerate. The principle of degeneration, recognised by Darwin as a possible, and, under certain conditions, a necessary consequence of his theory of natural selection, has been since advocated strongly by Dohrn, and later by Lankester in an Evening Discourse delivered before the Association at the Sheffield Meeting in 1879. Both Dohrn and Lankester suggested that degeneration occurred much more widely than was generally recognised.

In animals which are parasitic when adult, but free swimming in their early stages, as in the case of the Rhizocephala whose life history was so admirably worked out by Fritz Müller, degeneration is clear enough: so also is it in the case of the solitary Ascidians, in which the larva is a free swimming animal with a notochord, an elongated tubular nervous system, and sense organs, while the adult is fixed, devoid of the swimming tail, with no notochord, and with a greatly reduced nervous system and aborted sense organs.

In such cases the animal, when adult, is, as regards the totality of its organisation, at a distinctly lower morphological level, is less highly differentiated than it is when young, and during individual development there is actual retrograde development of important systems and organs.

About such cases there is no doubt: but we are asked to extend the idea of degeneration much more widely. It is urged that we ought not to demand direct embryological evidence before accepting a group as degenerate. We are reminded of the tendency to abbreviation or to complete omission of ancestral stages of which we have quoted examples above; and it is suggested that if such larval stages were omitted in all the members of a group we should have no direct evidence of degeneration in a group that might really be in an extremely degenerate condition.

Supposing, for instance, the free larval stages of the solitary Ascidians were suppressed, say through the acquisition of food yolk, then it is urged that the degenerate condition of the group might easily escape detection. The supposition is by no means extravagant; food yolk varies greatly in amount in allied animals, and cases like Hylodes, or amongst Ascidians Pyrosoma, show how readily a mere increase in the amount of food yolk in the egg may lead to the omission of important ancestral stages.

The question then arises whether it is not possible, or even probable, that animals which now show no indication of degeneration in their development are in reality highly degenerate, and whether it is not legitimate to suppose such degeneration to have occurred in the case of animals whose affinities are obscure or difficult to determine.

It is more especially with regard to the lower vertebrates that this argument has been employed; and at the present day, zoologists of authority, relying on it, do not hesitate to speak of such forms as Amphioxus and the Cyclostomes as degenerate animals, as wolves in sheep's clothing, animals whose simplicity is acquired and deceptive rather than real and ancestral.

I cannot but think that cases such as these should be regarded with some jealousy: there is at present a tendency to invoke degeneration rather freely as a talisman to extricate us from morphological difficulties; and an inclination to accept such suggestions, at any rate provisionally, without requiring satisfactory evidence in their support.

Degeneration of which there is direct embryological evidence stands on a very different footing from suspected degeneration, for which no direct evidence is forthcoming; and in the latter case the burden of proof undoubtedly rests with those who assume its existence.

The alleged instances among the lower vertebrates must be regarded particularly closely, because in their case the suggestion of degeneration is admittedly put forward as a means of escape from difficulties arising through theoretical views concerning the relation between vertebrates and invertebrates.

Amphioxus itself, so far as I can see, shows in its development no sign of degeneration, except possibly with regard to the anterior gut diverticula, whose ultimate fate is not altogether clear. With regard to the earlier stages of development, concerning which, thanks to the patient investigations of Kowalevsky and Hatschek, our knowledge is precise, there is no animal known to us in which the sequence of events is simpler or more straightforward. Its various organs and systems are formed in what is recognised as a primitive manner; and the development of each is a steady upward progress towards the adult condition. Food yolk, the great cause of distortion in development, is almost absent, and there is not the slightest indication of the former possession of a larger quantity. Concerning the later stages our knowledge is incomplete, but so much as has been ascertained gives no support to the suggestion of general degeneration.

Our knowledge of the conditions leading to degeneration is undoubtedly incomplete, but it must be noticed that the conditions usually associated with degeneration do not occur. Amphioxus is not parasitic, is not attached when adult, and shows no evidence of having formerly possessed food yolk in quantity sufficient to have led to the omission of important ancestral stages. Its small size as compared with other vertebrates is one of the very few points that can be referred to as possibly indicating degeneration, and will be considered more fully at a later point in my address.

A consideration of much less importance, but deserving of mention, is that in its mode of life Amphioxus not merely differs as already noticed from those groups of animals which we know to be degenerate, but agrees with some, at any rate, of those which there is reason to regard as primitive or persistent types. Amphioxus, like Balanoglossus, Lingula, Dentalium, and Limulus, is marine, and occurs in shallow water, usually with a sandy bottom, and, like the three smaller of these genera, it lives habitually buried almost completely in the sand, into which it burrows with great rapidity.

I do not wish to speak dogmatically. I merely wish to protest against a too ready assumption of degeneration; and to repeat that, so far as I can see, Amphioxus has not yet, either in its development, in its structure, or in its habits, been shown to present characters that suggest, still less that prove, the occurrence in it of general or extensive degeneration.

In a sense, all the higher animals are degenerate; that is, they can be shown to possess certain organs in a less highly developed condition than their ancestors, or even in a rudimentary state.

Thus a crab as compared with a lobster is degenerate in the matter of its tail, a horse as compared with Hipparion in regard to its outer toes; but it is neither customary nor advisable to speak of a crab as a degenerate animal compared to a lobster; to do so would be misleading. An animal should only be spoken of as degenerate when the retrograde development is well marked, and has affected not one or two organs only, but the totality of its organisation.

It is impossible to draw a sharp line in such cases, and to limit precisely the use of the term degeneration. It must be borne in mind that no animal is at the top of the tree in all respects. Man himself is primitive as regards the number of his toes, and degenerate in respect to his ear muscles; and between two animals even of the same group it may be impossible to decide which of the two is to be called the higher and which the lower form.

Thus, to compare an oyster with a mussel. The oyster is more primitive than the mussel as regards the position of the ventricle of the heart and its relations to the alimentary canal; but is more modified in having but a single adductor muscle; and almost certainly degenerate in being devoid of a foot.

Care must also be taken to avoid speaking of an animal as degenerate in regard to a particular organ merely because that organ is less fully developed than in allied animals. An organ is not degenerate unless its present possessor has it in a less perfect condition than its ancestors had.

A man is not degenerate in the matter of the length of his neck as compared with a giraffe, nor as compared with an elephant in respect of the size of his front teeth, for neither elephant nor giraffe enters into the pedigree of man. A man is, however, degenerate, whoever his ancestors may have been, in regard to his ear muscles; for he possesses these in a rudimentary and functionless condition, which can only be explained by descent from some better equipped progenitor.

Closely connected with the question of degeneration is that of the size of animals, and its bearing on their structure and development; a problem noticed by many writers, but which has perhaps not yet received the attention it merits.

If we are right in interpreting the eggs of Metazoa as representing the unicellular or protozoan stage in their ancestry, then the small size of the egg may be viewed as recapitulatory.

But the gradual increase in size of the embryo, and its growth up to the adult condition, can only be regarded as representing in a most general way, if at all, the actual or even the relative sizes of the intermediate ancestral stages of the pedigree.

It is quite true that animals belonging to the lower groups are, as a general rule, of smaller size than those of higher grade; and also that the giants are met with among the highest members of each division. Cephalopoda are the highest molluscs, and the largest cephalopods greatly exceed in size any other members of the group; decapods are at once the highest and the largest crustaceans; and whales, the hugest animals that exist, or, so far as we know, that ever have existed, belong to the highest group of all, the mammalia. It would be easy to quote exceptions, but the general rule obtains admittedly.

However, although there may be, and probably is, a general parallelism between the increase in size from the egg to the adult, and the historical increase in size during the passage from lower to higher forms; yet no one could maintain that the sizes of embryos represent at all correctly those of the ancestors; that, for instance, the earliest birds were animals the size of a chick embryo at a time when avian characters first declare themselves, or that the ancestral series in all cases presented a steady progression in respect of actual magnitude.

In the lower animals, *e.g.*, in Orbitolites, the actual size of the several ancestral stages is probably correctly recapitulated during the growth of the adult; and it is very possible that it is so also in such forms as the solitary sponges. In higher animals, except in the early stages of those forms which are practically devoid of food yolk, and which hatch as pelagic larvæ, this certainly does not obtain.

This is clear enough, but is worth pointing out, for if, as most certainly is the case, the embryos of animals are actually smaller than the ancestral forms they represent, it is possible that the smallness of the embryo may have had some influence on its organisation, and be responsible for some of the modifications in the ancestral history; and more especially for the disappearance of ancestral organs in free swimming larvæ.

In adult animals the relation between size and structure has been very clearly pointed out by Herbert Spencer. Increased size involves by itself increased complexity of structure; the determining consideration being that while the surface area of the body increases as the squares of the linear dimensions, the mass of the body increases as their cubes.

If, for example, we imagine two animals of similar shape and proportions, but of different size—for the sake of simplicity, we may suppose them to be spherical, and that the diameter of one is twice that of the other—then the larger one will have four times the extent of surface of the smaller, but eight times its mass or bulk: and it is quite possible that while the extent of surface, or skin, in the smaller animal might suffice for the necessary respiratory and excretory interchanges, it would be altogether insufficient in the larger animal, in which increased extent of surface must be provided by foldings of the skin, as in the form of gills.

To take an actual instance; Limapontia is a minute nudibranchiate, or sea-slug, about the sixth of an inch in length; it has a smooth body, totally devoid of respiratory processes, while forms allied to it, but of larger size, have their extent of surface increased by branching processes, which often take the form of specialised gills.

This is a peculiarly instructive case, because Limapontia in its early developmental stages possesses a large spirally-coiled shell, and shows other evidence of descent from forms with specialised breathing organs. We are certainly right in associating the absence of respiratory organs in the adult with the small size of the animal; and comparison with allied forms suggests very strongly that there has been in its pedigree an actual reduction of size, which has led to the degeneration of the respiratory organs.

This is an important conclusion: it is a well-known fact that the smaller members of a group are, as a rule, more simply organised than the larger members, especially with regard to their respiratory and circulatory systems; but if we are right in concluding that reduction in size may be an actual cause of simplification or degeneration in structure, then we must be on our guard against assuming hastily that these smaller and simpler animals are necessarily primitive in regard to the groups to which they belong. It is possible, for instance, that the simplification or even absence of respiratory organs seen in Pauropus, in the Thysanura, and in other small Tracheata, may be a secondary character, acquired through reduction of size.

An interesting illustration of the law discussed above is afforded by the brains of mammals; it has been noticed by many anatomists that the extent of convolution, or folding of the surface of the cerebral hemispheres in mammals, is related not to the degree of intelligence of the animal, but to its actual size, a beaver having an almost smooth brain and a cow a highly complicated one. Jelgersma, and, independently of him, Professor Fitzgerald,[1] have explained this as due to the necessity of preserving the due proportion between the outer layer of grey matter or cortex, which is approximately uniform in thickness, and the central mass of white matter. But for the foldings of the surface the proportion of white matter to grey matter would be far higher in a large than in a small brain.

It must not be forgotten, on the other hand, that many zoologists hold the view, in favour of which the evidence is steadily increasing, that the primitive or ancestral members of each group were of small size. Thus Fürbringer remarks with regard to birds, that on the whole small birds show more primitive and simpler conditions of structure than the larger members of the same group. He expresses the opinion that the first birds were probably smaller than Archæopteryx, and notes that reptiles and mammals also show in their earlier and smaller types more primitive features than do their larger descendants. Finally, Fürbringer concludes that 'it is therefore the study of the smaller members within given groups of animals which promises the best results as to their phylogeny.'

Again, one of the most striking points with regard to the pedigree of the horse, as agreed on by palæontologists, is the progressive reduction in size which we meet with as we pass backwards in time from stage to stage. The Pliocene Hipparion was smaller than the existing horse, in fact about the size of a donkey; the Miocene Mesohippus about equalled a sheep; while Eohippus, from the Lower Eocene deposits, was no larger than a fox. Not only is there good reason for holding that, as a rule, larger animals are descended from ancestors of smaller size, but there is also much evidence to show that increase in size beyond certain limits is disadvantageous, and may lead to destruction rather than to survival. It has happened more than once in the history of the world, and in more than one group of animals, that gigantic stature has been attained immediately before extinction of the group, a final and tremendous effort to secure survival, but a despairing and unsuccessful one. The Ichthyosauri, Plesiosauri, and other extinct reptilian groups, the Moas, and the huge extinct Edentates, are well-known examples, to which before long will be added the elephants and the whales, and, it may be, ironclads as well.

The whole question of the influence of size is of the greatest possible interest and importance, and it is greatly to be hoped that it will not be permitted to remain in its present uncertain and unsatisfactory condition.

It may be suggested that Amphioxus is an animal which has undergone reduction in size, and that its structural simplicity may, like that of Limapontia, be due, in part at least, to this reduction. Such evidence as we have tells against this suggestion; the first system to undergo degeneration in consequence of a reduction in size is the respiratory, and the respiratory organs of Amphioxus, though very simple, are also, for a vertebrate, unusually extensive.

[1] Cf. *Nature*, June 5, 1890, p. 125.

We have now considered the more important of the influences which are recognised as affecting developmental history in such a way as to render the recapitulation of ancestral stages less complete than it might otherwise be, which tend to prevent ontogeny from correctly repeating the phylogenetic history. It may at this point reasonably be asked whether there is any way of distinguishing the palingenetic history from the later cenogenetic modifications grafted on to it; any test by which we can determine whether a given larval character is or is not ancestral.

Most assuredly there is no one rule, no single test, that will apply in all cases; but there are certain considerations which will help us, and which should be kept in view.

A character that is of general occurrence among the members of a group, both high and low, may reasonably be regarded as having strong claims to ancestral rank; claims that are greatly strengthened if it occurs at corresponding developmental periods in all cases; and still more if it occurs equally in forms that hatch early as free larvæ, and in forms with large eggs, which develop directly into the adult. As examples of such characters may be cited the mode of formation and relations of the notochord, and of the gill clefts of vertebrates, which satisfy all the conditions mentioned.

Characters that are transitory in certain groups, but retained throughout life in allied groups, may, with tolerable certainty, be regarded as ancestral for the former; for instance, the symmetrical position of the eyes in young flat fish, the spiral shell of the young limpet, the superficial positions of the madreporite in Elasipodous Holothurians, or the suckerless condition of the ambulacral feet in many Echinoderms.

A more important consideration is that if the developmental changes are to be interpreted as a correct record of ancestral history, then the several stages must be possible ones, the history must be one that could actually have occurred, *i.e.*, the several steps of the history as reconstructed must form a series, all the stages of which are practicable ones.

Natural selection explains the actual structure of a complex organ as having been acquired by the preservation of a series of stages, each a distinct, if slight, advance on the stage immediately preceding it, an advance so distinct as to confer on its possessor an appreciable advantage in the struggle for existence. It is not enough that the ultimate stage should be more advantageous than the initial or earlier condition, but each intermediate stage must also be a distinct advance. If then the development of an organ is strictly recapitulatory, it should present to us a series of stages, each of which is not merely functional, but a distinct advance on the stage immediately preceding it. Intermediate stages, *e.g.*, the solid œsophagus of the tadpole, which are not and could not be functional, can form no part of an ancestral series; a consideration well expressed by Sedgwick[1] thus: 'Any phylogenetic hypothesis which presents difficulties from a physiological standpoint must be regarded as very provisional indeed.'

A good example of an embryological series fulfilling these conditions is afforded by the development of the eye in the higher Cephalopoda. The earliest stage consists in the depression of a slightly modified patch of skin; round the edge of the patch the epidermis becomes raised up as a rim; this gradually grows inwards from all sides, so that the depressed patch now forms a pit, communicating with the exterior through a small hole or mouth. By further growth the mouth of the pit becomes still more narrowed, and ultimately completely closed, so that the pit becomes converted into a closed sac or vesicle; at the point at which final closure occurs formation of cuticle takes place, which projects as a small transparent drop into the cavity of the sac; by formation of concentric layers of cuticle this drop becomes enlarged into the spherical transparent lens of the eye, and the development is completed by histological changes in the inner wall of the vesicle, which convert it into the

[1] Sedgwick, 'On the Early Development of the Anterior Part of the Wolffian Duct and Body in the Chick,' *Quarterly Journal of Microscopical Science*, vol. xxi. 1881, p. 456.

retina, and by the formation of folds of skin around the eye, which become the iris and the eyelids respectively.

Each stage in this developmental history is a distinct advance, physiologically, on the preceding stage, and, furthermore, each stage is retained at the present day as the permanent condition of the eye in some member of the group Mollusca.

The earliest stage, in which the eye is merely a slightly depressed and slightly modified patch of skin, represents the simplest condition of the Molluscan eye, and is retained throughout life in Solen. The stage in which the eye is a pit, with widely open mouth, is retained in the limpet; it is a distinct advance on the former, as through the greater depression the sensory cells are less exposed to accidental injury.

The narrowing of the mouth of the pit in the next stage is a simple change, but a very important step forwards. Up to this point the eye has served to distinguish light from darkness, but the formation of an image has been impossible. Now, owing to the smallness of the aperture, and the pigmentation of the walls of the pit which accompanies the change, light from any one part of an object can only fall on one particular part of the inner wall of the pit or retina, and so an image, though a dim one, is formed. This type of eye is permanently retained in the Nautilus.

The closing of the mouth of the pit by a transparent membrane will not affect the optical properties of the eye, and will be a gain, as it will prevent the entrance of foreign bodies into the cavity of the eye.

The formation of the lens by deposit of cuticle is the next step. The gain here is increased distinctness and increased brightness of the image, for the lens will focus the rays of light more sharply on the retina, and will allow a greater quantity of light, a larger pencil of rays from each part of the object, to reach the corresponding part of the retina. The eye is now in the condition in which it remains throughout life in the snail and other gastropods. Finally the formation of the folds of skin known as iris and eyelids provides for the better protection of the eye, and is a clear advance on the somewhat clumsy method of withdrawal seen in the snail.

The development of the vertebrate liver is another good but simpler example. The most primitive form of the liver is that of Amphioxus, in which it is present as a simple saccular diverticulum of the intestinal canal, with its wall consisting of a single layer of cells, and with bloodvessels on its outer surface. The earliest stage in the formation of the liver in higher vertebrates, the frog for instance, is practically identical with this. In the frog the next stage consists in folding of the wall of the sac, which increases the efficiency of the organ by increasing the extent of surface in contact with the bloodvessels. The adult condition is attained simply by a continuance of this process; the foldings of the wall becoming more and more complicated, but the essential structure remaining the same—a single layer of epithelial cells in contact on one side with bloodvessels, and bounding on the other directly or indirectly the cavity of the alimentary canal.

It is not always possible to point out the particular advantage gained at each step even when a complete developmental series is known to us, but in such cases as, for instance, in Orbitolites, our difficulties arise chiefly from ignorance of the particular conditions that confer advantage in the struggle for existence in the case of the forms we are dealing with.

The early larval stages in the development of animals, and more especially those that are marine and pelagic in habit, have naturally attracted much attention, since in the absence, probably inevitable, of satisfactory palæontological evidence, they afford us the sole available clue to the determination of the mutual relations of the large groups of animals, or of the points at which these diverged from one another.

In attempting to interpret these early ontogenetic stages as actual ancestral forms, beyond which development at one time did not proceed, we must keep clearly in view the various disturbing causes which tend to falsify the ancestral record; such as the influence of food yolk, or of habitat, and the tendency of diminution in size to give rise to simplification of structure, a point of importance if it be granted that these free larvæ are of smaller size than the ancestral forms to which they correspond.

If, on the other hand, in spite of these powerful modifying causes, we do find a particular larval form occurring widely and in groups not very closely akin, then we certainly are justified in attaching great importance to it, and in regarding it as having strong claims to be accepted as ancestral for these groups.

Concerning these larval forms, and their possible ancestral significance, our knowledge has made no great advance since the publication of Balfour's memorable chapter on this subject; and I propose merely to allude briefly to a few of the more striking instances.

The earliest, the most widely spread, and the most famous of larval forms is the gastrula, which occurs in a simple or in a modified form in some members of each of the large animal groups. It is generally admitted that its significance is the same in all cases, and the evidence is very strong in favour of regarding it as a stage ancestral for all Metazoa. The difficulty arising from its varying mode of development in different forms is, however, still unsolved, and embryologists are not yet agreed whether the invaginate or delaminate form is the more primitive. In favour of the former is its much wider occurrence; in favour of the latter the fact that it is easy to picture a series of stages leading gradually from a unicellular protozoon to a blastula, a diblastula, and ultimately a gastrula, each stage being a distinct advance, both morphological and physiological, on the preceding stage; while in the case of the invaginate gastrula it is not easy to imagine any advantage resulting from a flattening or slight pitting in of one part of the surface, sufficient to lead to its preservation and further development.

Of larval forms later than the gastrula, the most important by far is the Pilidium larva, from which it is possible, as Balfour has shown, that the slightly later Echinoderm larva, as well as the widely spread Trochosphere larva, may both be derived. Balfour concludes that the larval forms of all Cœlomata, excluding the crustacea and vertebrates, may be derived from one common type, which is most nearly represented now by the Pilidium larva, and which 'was an organism something like a Medusa, with a radial symmetry.' The tendency of recent phylogenetic speculations is to accept this in full, and to regard as the ancestor of Turbellarians and of all higher forms, a jelly-fish or ctenophoran, which in place of swimming freely has taken to crawling on the sea bottom.

Of the two groups excluded above, the crustacea and the vertebrata, the interest of the former centres in the much discussed problem of the significance of the Nauplius larva. There is now a fairly general agreement that the primitive crustacea were types akin to the phyllopods, *i.e.*, forms with elongated and many-segmented bodies, and a large number of pairs of similar appendages. If this is correct, then the explanation of the Nauplius stage must be afforded by the phyllopods themselves, and it is no use looking beyond this group for it. A Nauplius larva occurs in other crustacea merely because they have inherited from their phyllopod ancestors the tendency to develop such a stage, and it is quite legitimate to hold that higher crustaceans are descended from phyllopods, and that the Nauplius represents in more or less modified form an earlier ancestor of the phyllopods themselves.

As to the Nauplius itself the first thing to note is that though an early larval form it cannot be a very primitive form, for it is already an unmistakable crustacean; the absence of cilia, the formation of a cuticular investment, the presence of jointed schizopodous limbs, together with other anatomical characters, proving this point conclusively. It follows therefore either that the earlier and more primitive stages are entirely omitted in the development of crustacea, or else that the Nauplius represents such an early ancestral stage with crustacean characters, which properly belong to a later stage, thrown back upon it and precociously developed.

The latter explanation is the one usually adopted; but before the question can be finally decided more accurate observations than we at present possess are needed concerning the stages intermediate between the egg and the Nauplius.

The absence of a heart in the Nauplius may reasonably be associated with the small size of the larva.

Concerning the larval forms of vertebrates, it is only in Amphioxus and the

Ascidians that the earliest larval stages are free-living, independent animals. In both groups the most characteristic larval stage is that in which a notochord is present, and a neural tube, open in front, and communicating behind through a neurenteric canal with the digestive cavity, which has no other opening to the exterior. This is a very early stage, both in Amphioxus and Ascidians; but, so far as we know, it cannot be compared with any invertebrate larva. It is customary, in discussions on the affinities of vertebrates, to absolutely ignore the vertebrate larval forms, and to assume that their peculiarities are due to precocious development of vertebrate characteristics. It may turn out that this view of the matter is correct; but it has certainly not yet been proved to be so, and the development of both Amphioxus and Ascidians is so direct and straightforward that evidence of some kind may reasonably be required before accepting the doctrine that this development is entirely deceptive with regard to the ancestry of vertebrates.

Zoologists have not quite made up their minds what to do with Amphioxus: apparently the most guileless of creatures, many view it with the utmost suspicion, and not merely refuse to accept its mute protestations of innocence, but regard and speak of it as the most artful of deceivers. Few questions at the present day are in greater need of authoritative settlement.

That ontogeny really is a repetition of phylogeny must, I think, be admitted, in spite of the numerous and various ways in which the ancestral history may be distorted during actual development.

Before leaving the subject, it is worth while inquiring whether any explanation can be found of recapitulation. A complete answer can certainly not be given at present, but a partial one may, perhaps, be obtained.

Darwin himself suggested that the clue might be found in the consideration that at whatever age a variation first appears in the parent, it tends to reappear at a corresponding age in the offspring; but this must be regarded rather as a statement of the fundamental fact of embryology than as an explanation of it.

It is probably safe to assume that animals would not recapitulate unless they were compelled to do so: that there must be some constraining influence at work, forcing them to repeat more or less closely the ancestral stages. It is impossible for instance to conceive what advantage it can be to a reptilian or mammalian embryo to develop gill clefts which are never used, and which disappear at a slightly later stage; or how it can benefit a whale, that in its embryonic condition it should possess teeth which never cut the gum, and which are lost before birth.

Moreover, the history of development in different animals or groups of animals, offers to us, as we have seen, a series of ingenious, determined, varied, but more or less unsuccessful efforts to escape from the necessity of recapitulating, and to substitute for the ancestral process a more direct method.

A further consideration of importance is that recapitulation is not seen in all forms of development, but only in sexual development; or, at least, only in development from the egg. In the several forms of asexual development, of which budding is the most frequent and most familiar, there is no repetition of ancestral phases; neither is there in cases of regeneration of lost parts, such as the tentacle of a snail, the arm of a starfish, or the tail of a lizard; in such regeneration it is not a larval tentacle, or arm, or tail, that is produced, but an adult one.

The most striking point about the development of the higher animals is that they all alike commence as eggs. Looking more closely at the egg and the conditions of its development, two facts impress us as of special importance: first, the egg is a single cell, and therefore represents morphologically the Protozoan, or earliest ancestral phase; secondly, the egg, before it can develop, must be fertilised by a spermatozoon, just as the stimulus of fertilisation by the pollen grain is necessary before the ovum of a plant will commence to develop into the plant-embryo.

The advantage of cross-fertilisation in increasing the vigour of the offspring is well known, and in plants devices of the most varied and even extraordinary kind are adopted to ensure that such cross-fertilisation occurs. The essence of the act of cross-fertilisation, which is already established among Protozoa, consists in combination of the nuclei of two cells, male and female, derived from different individuals. The nature of the process is of such a kind that two individual cells are alone concerned in it; and it may, I think, be reasonably argued that the reason why animals commence their existence as eggs, *i.e.*, as single cells, is because it is in this way only that the advantage of cross-fertilisation can be secured, an advantage admittedly of the greatest importance, and to secure which natural selection would operate powerfully.

The occurrence of parthenogenesis, either occasionally or normally, in certain groups is not, I think, a serious objection to this view. There are very strong reasons for holding that parthenogenetic development is a modified form, derived from the sexual method. Moreover, the view advanced above does not require that cross-fertilisation should be essential to individual development, but merely that it should be in the highest degree advantageous to the species, and hence leaves room for the occurrence, exceptionally, of parthenogenetic development.

If it be objected that this is laying too much stress on sexual reproduction, and on the advantage of cross-fertilisation, then it may be pointed out in reply that sexual reproduction is the characteristic and essential mode of multiplication among Metazoa: that it occurs in all Metazoa, and that when asexual reproduction, as by budding, &c., occurs, this merely alternates with the sexual process which, sooner or later, becomes essential.

If the fundamental importance of sexual reproduction to the welfare of the species be granted, and if it be further admitted that Metazoa are descended from Protozoa, then we see that there is really a constraining force of a most powerful nature compelling every animal to commence its life history in the unicellular condition, the only condition in which the advantage of cross-fertilisation can be obtained; *i.e.*, constraining every animal to begin its development at its earliest ancestral stage, at the very bottom of its genealogical tree.

On this view the actual development of any animal is strictly limited at both ends: it must commence as an egg, and it must end in the likeness of the parent. The problem of recapitulation becomes thereby greatly narrowed; all that remains being to explain why the intermediate stages in the actual development should repeat the intermediate stages of the ancestral history.

Although narrowed in this way, the problem still remains one of extreme difficulty.

It is a consequence of the Theory of Natural Selection that identity of structure involves community of descent: a given result can only be arrived at through a given sequence of events: the same morphological goal cannot be reached by two independent paths. A negro and a white man have had common ancestors in the past; and it is through the long-continued action of selection and environment that the two types have been gradually evolved. You cannot turn a white man into a negro merely by sending him to live in Africa: to create a negro the whole ancestral history would have to be repeated; and it may be that it is for the same reason that the embryo must repeat or recapitulate its ancestral history in order to reach the adult goal.

I am not sure that we can at present get much further; but the above considerations give opportunity for brief notice of what is perhaps the most noteworthy of recent embryological papers, Kleinenberg's remarkable monograph on Lopadorhynchus.

Kleinenberg directs special attention to what is known to evolutionists as the difficulty with regard to the origin of new organs, which is to the effect that although natural selection is competent to account for any amount of modification in an organ after it has attained a certain size, and become of functional importance, yet that it cannot account for the earliest stages in the formation of an organ before it has become large enough or sufficiently developed to be of real use. The difficulty is a serious one; it is carefully considered by Mr. Darwin, and met completely in certain cases; but, as Kleinenberg correctly states, no general explanation has been offered with regard to such instances.

As such general explanation Kleinenberg proposes his theory of the development of organs by substitution. He points out that any modification of an organ or tissue must involve modification, at least in functional activity, of other organs. He then continues by urging that one organ may replace or be substituted for another, the replacing organ being in no way derived morphologically from the replaced or preceding organ, but having a genetic relation to it of this kind, that it can only arise in an organism so constituted, and is dependent on the prior existence of the replaced organ, which supplies the necessary stimulus for its formation.

As an example he takes the axial skeleton of vertebrates. The notochord, formed by change of function from the wall of the digestive canal, is the sole skeleton of the lowest vertebrates, and the earliest developmental phase in all the higher forms. The notochord gives rise directly to no other organ, but is gradually replaced by other and unlike structures by substitution. The notochord is an intermediate organ, and the cartilaginous skeleton which replaces it is only intelligible through the previous existence of the notochord; while, in its turn, the cartilaginous skeleton gives way, being replaced, through substitution, by the bony skeleton.

The successive phases in the evolution of weapons might be quoted as an illustration of Kleinenberg's theory. The bow and arrow is a better weapon than a stick or stone; it is used for the same purpose, and the importance or need for a better weapon led to the replacement of the sling by the bow; the bow does not arise by further development or increasing perfection of the sling: it is an entirely new weapon, towards the formation of which the older and more primitive weapons have acted as a stimulus, and which has replaced these latter by substitution, while the substitution at a later date of firearms for the bow and arrow is merely a further instance of the same principle.

It is too early yet to realise the full significance of Kleinenberg's most suggestive theory; but if it be really true that each historic stage in the evolution of an organ is necessary as a stimulus to the development of the next succeeding stage, then it becomes clear why animals are constrained to recapitulate. Kleinenberg suggests further that the extraordinary persistence in embryonic life of organs which are rudimentary and functionless in the adult may also be explained by his theory, the presence of such organs in the embryo being indispensable as a stimulus to the development of the permanent structures of the adult.

It would be easy to point out difficulties in the way of the theory. The omission of historic stages in the actual ontogenetic development, of which almost all groups of animals supply striking examples, is one of the most serious; for if these stages are necessary as stimuli for the succeeding stages, then their omission requires explanation; while, if such stimuli are not necessary, the theory would appear to need revision.

Such objections may, however, prove to be less serious than they appear at first sight; and in any case Kleinenberg's theory may be welcomed as an important and original contribution, which deserves—indeed demands—the fullest and most careful consideration from all morphologists, and which acquires special interest from the explanation which it offers of recapitulation as a mechanical process, through which alone is it possible for an embryo to attain the adult structure.

That recapitulation does actually occur, that the several stages in the development of an animal are inseparably linked with and determined by its ancestral history, must be accepted. 'To take any other view is to admit that the structure of animals and the history of their development form a mere snare to entrap our judgment.'

Embryology, however, is not to be regarded as a master-key that is to open the gates of knowledge and remove all obstacles from our path without further trouble on our part; it is rather to be viewed and treated as a delicate and complicated instrument, the proper handling of which requires the utmost nicety of balance and adjustment, and which, unless employed with the greatest skill and judgment, may yield false instead of true results.

Embryology is indeed a most powerful and efficient aid, but it will not, and cannot, provide us with an immediate or complete answer to the great riddle of life. Complications, distortions, innumerable and bewildering, confront us at every step, and the progress of knowledge has so far served rather to increase the number and magnitude of these pitfalls than to teach us how to avoid them.

Still, there is no cause for despair—far from it; if our difficulties are increasing, so also are our means of grappling with them; if the goal appears harder to reach than we thought for, on the other hand its position is far better defined, and the means of approach, the lines of attack, are more clearly recognised.

One thing above all is apparent, that embryologists must not work single-handed, and must not be satisfied with an acquaintance, however exact, with animals from the side of development only; for embryos have this in common with maps, that too close and too exclusive a study of them is apt to disturb a man's reasoning power.

Embryology is a means, not an end. Our ambition is to explain in what manner and by what stages the present structure of animals has been attained. Towards this embryology affords most potent aid; but the eloquent protest of the great anatomist of Heidelberg must be laid to heart, and it must not be forgotten that it is through comparative anatomy that its power to help is derived.

What would it profit us, as Gegenbaur justly asks, to know that the higher vertebrates when embryos have slits in their throats, unless through comparative anatomy we were acquainted with forms now existing in which these slits are structures essential to existence? Anatomy defines the goal, tells us of the things that have to be explained; embryology offers a means, otherwise denied to us, of attaining it.

Comparative anatomy and palæontology must be studied most earnestly by those who would turn the lessons of embryology to best account, and it must never be forgotten that it is to men like Johannes Müller, Stannius, Cuvier, and John Hunter, the men to whom our exact knowledge of comparative anatomy is due, that we owe also the possibility of a science of embryology.

The following Paper and Reports were read:—

1. *On the Ornithology of the Sandwich Islands.* *By* Professor A. NEWTON, *F.R.S.*

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2. *Report of the Committee to Improve and Experiment with a Deep-Sea Tow-Net.* See Reports, p. 471.

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3. *Report of the Committee on the Naples Zoological Station.* See Reports, p. 449.

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4. *Third Report of the Committee on the Flora and Fauna of the West India Islands.*—See Reports, p. 447.

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5. *Third Report of the Committee on the Disappearance of Native Plants from their Local Habitats.*—See Reports, p. 465.

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6. *Fourth Report of the Committee for establishing a Botanical Station at Paradeniya, Ceylon.*—See Reports, p. 470.

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7. *Report of the Committee on the Migration of Birds.* See Reports, p. 464.

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8. *Report of the Committee appointed to arrange for the Occupation of a Table at the Marine Biological Laboratory, Plymouth.*—See Reports, p. 444.

9. *Report of the Committee on the Invertebrate Fauna and Cryptogamic Flora of the Fresh Waters of the British Isles.*

FRIDAY, SEPTEMBER 5.

The following Papers were read:—

1. *Discussion on the Teaching of Botany, opened by* Professors MARSHALL WARD, F. OLIVER, *and* F. O. BOWER.

2. *On the Cretaceous Mammals of North America.* *By* Professor O. C. MARSH.

Remains of mammals have long been known from the Triassic and Jurassic formations, both in the Old World and in the New, all indicating animals of small size and low organisation. None were known from the Cretaceous, but in the Tertiary above this class was dominant, and even at the base of the formation was represented by many and various forms.

A comparison of the mammals from the Jurassic and Tertiary made it certain that intermediate forms must exist in the Cretaceous, and for many years special search has been made for them in various countries, but until recently without success. The most promising field was evidently in the Rocky Mountain region, and here a systematic search had been made. A few fragmentary remains were found in 1882, but not in place. The author has since secured from the Laramie formation more than a thousand specimens of mammalian remains, including jaws, teeth, and various portions of the skeleton, most of them in good preservation. They represent many new genera and species, and were all found in the typical Laramie, either in place, or in association with other fossils that determine their geological position beyond doubt.[1]

The vertebrate fossils found with them are mainly remains of Dinosaurs, which are represented by several families. The most abundant specimens belong to the *Ceratopsidæ*, and with these are others allied to *Megalosaurus*, *Hadrosaurus*, and related forms. Crocodiles, turtles, and various fishes, mostly ganoids, are also represented in the same deposits, which have been named by the author the Ceratops beds.

The mammalian remains themselves also, to some extent, indicate their horizon, and this is one of the interesting points connected with the discovery. Many of them belong to the group the author has called the *Allotheria*, which contains the Triassic *Triglyphus*, *Tritylodon*, and *Microlestes*, the Jurassic *Stereognathus*, *Plagiaulax*, and *Bolodon* in Europe, and *Allodon* and *Ctenacodon* in America, as well as some later forms.

Most of the genera show close affinities with the Triassic and Jurassic types, and one genus cannot at present be distinguished from *Dryolestes*. Another genus appears more like an insectivore, with teeth of the same general form as *Tupaia*. Besides these, there are several genera of small marsupials, which, although quite distinct, seem to have near affinities with some American Tertiary forms, or others still existing, especially the Opossums.

Carnivores, rodents, and ungulates appear to be entirely wanting in this unique fauna. A still more surprising fact is the absence of their probable ancestors, unless, indeed, the insectivorous forms are entitled to this important position.

[1] *American Journal of Science*, vol. xxxviii. pp. 81–92, plates ii.–v. and pp. 177–80, plates vii.–viii. August 1889.

As a whole, the mammals already found in these deposits are very nearly what was expected from the Cretaceous, but thus far the older types predominate. The *Allotheria* from this horizon appear to be distinct from the *Marsupialia*, and some of the specimens secured point to the Monotremes as possible allies. One genus, at least, of the new forms has a free coracoid, as well as some other characters of Monotremes.

Characteristic teeth of the principal known genera of Cretaceous mammals were exhibited by the author, who pointed out the close relationship of many of them with Jurassic forms. All the Cretaceous mammals yet discovered are very small in size, and all are from essentially the same horizon. They indicate a rich and varied mammalian fauna in the Cretaceous period, but as a whole they are Mesozoic in type. The ancestors of most of the Tertiary mammals are yet to be discovered.

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3. *On Androgynous Cones in* Pinus Thunbergii, *and some remarks on their Morphology. By* F. Ernest Weiss.

The author described some male cones of Pinus Thunbergii (Massoniana), in which the lower portion bore stamens, the upper portion ovuliferous scales subtended by the usual bract scales. Such cones had been described by Dr. Masters for this species of Pinus, but were stated by him to be modified female cones. Among the transition stages from the male to the female portion of the cones, Mr. Weiss described and figured some which had not previously been observed in the numerous cases of androgynous cones examined by Mohl, Kramer, Dickson, Oerstedt, and Masters. Above the ordinary staminal leaf he found one stamen subtending a second stamen, and transition stages in which the upper stamen was replaced by a rudimentary stamen, and finally by an ovuliferous scale. Hence he concluded that the ovuliferous scale was a leaf-structure, and not a modified shoot, as held by Strassburger, Dickson, and Masters, nor a fusion of two leaves as considered by Celakovsky, Velenovsky, and others.

He also found stages in which the upper stamen persisted, but the subtending stamen had become replaced by a bract scale. This afforded additional proof that the ovuliferous scale was of the same nature as the single upper stamen, and morphologically its equivalent. The writer then criticised Velenovsky's last contribution to the question of the morphology of the female cone (Flora, 1888), and finally supported Eichler's view that the bract scale and the ovuliferous scale are parts of a single leaf, illustrating this view by the stages described above.

The stamen arising seemingly in the axil of a subtending stamen he considered as a double stamen, formed either by 'dedoublement' or by reversion to an ancestral peltate stamen with four sporangia, and derivable from a multisporangiate stamen of a Cycad. The upper portion of the stamen usually disappeared in the group of the Coniferæ. In the same way the female cone could be derived from a female cone of a Cycad by a division of the carpel into two, the upper portion carrying the ovules, the lower portion sterile, but probably with some function such as keeping the cone open during the time of pollination, and then becoming in most cases unimportant and inconspicuous. The female cones of Pinus would therefore be equivalent to those of Araucaria or the Cycads, and be of the nature of flowers, like the male cone, and not as Celakovsky would have it, inflorescence.

The androgynous cone above described would be of the nature of an hermaphrodite flower, and not a mixture of flower and inflorescence as it would be according to Celakovsky's interpretation.

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4. *On a curious Cell-content in* Eucommia ulmoides (*Oliv.*). *By* F. Ernest Weiss.

Some bark of this remarkable tree (Tu-chung) from Central China was given the author for examination by Professor Oliver. The bark, and leaves also to a slight extent, show when broken asunder a number of silky-looking threads, which are very elastic, but after a certain degree of tension very extensible. These threads, insoluble in acids, alkalies, or alcohol, swell up greatly in chloroform, turpentine, or benzole, and are to a certain extent soluble in these substances when heated. If the threads are heated dry they readily melt. This would indicate them to be of the nature of resin or balsam. When examined microscopically these threads are seen to run longitudinally in the inner cortex occasionally, but most frequently in the phloem, between the sieve-tubes and the well-marked companion cells. Only in a single instance was one seen to branch. In the leaf they accompany the vascular bundles generally on both sides of the phloem, and terminate among the collecting cells on the upper side of the leaf.

In the fruit which the author had examined the threads are much more numerous, and are shown to be contained in cells which have a thicker cellulose wall here than in the phloem, where they are very delicate indeed. He takes them to be of the nature of latex cells, though their contents are more homogeneous, never showing starch grains or other granules. It is curious to find this resinous substance within the cells, in spite of the statements of De Bary, Tsirch, and Volkens, that these substances are never found as such within the cells, but are passed through the cell wall as resinogenous substances, and that the resin itself is formed outside the cell.

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5. *On an Abnormality in* Tropæolum, *with remarks on the origin of the Spur. By* Professor A. Denny.

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6. *Notes on the Natural History of Hierro and Graciosa, two outlying members of the Canary Islands. By* the Rev. Canon Tristram, *F.R.S.*

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7. *Contributions to a Knowledge of the Composition of the Human Lens, especially in reference to the changes it undergoes with age and in cataract. By* William Job Collins, *M.D., M.S., B.Sc., F.R.C.S.*

This research was undertaken as being ancillary to the question of the propriety of extraction of immature cataracts. It was found that information on the subject of the varying composition of the human lens in regard to solids, water, &c., in relation to age was very meagre. The difficulty of obtaining clear, fresh, human lenses for analysis restricted the number of observations and extended the duration of the research; the value of the data obtained is enhanced by the identity of procedure in each case. Post-mortem material was not employed. Incidentally the research corroborated some previous work on the increased weight of the lens with advancing age. The weight, total solids, water, and ash, and the percentage proportion of the three last to the first, are set forth in the case of twelve clear human lenses at ages 4 to 68 in the following table:

No.	Age	Total Weight	Water	Solids	Ash	Percentum		
						Water	Solids	Ash
1	4	·151	·103	·048	·003	68	32	1·9
2	6	·183	·139	·044	·002	76	24	1·0
3	7	·143	·096	·047	·001	67	33	·7
4	9	·180	·109	·071	·001	61	39	·5
5	10	·163	·113	·050	·001	69	31	·6
6	11	·200	·154	·046	·001	77	23	·5
7	26	·215	·153	·062	·002	71	29	·9
8	27	·188	·136	·052	·001	72	28	·5
9	28	·1915	·132	·0595	·002	69	31	1·0
10	40	·2175	·1575	·060	·001	72	28	·5
11	64	·247	·176	·071	·001	71	29	·4
12	68	·210	·135	·075	·003	64	36	1·4
Average . .		·1908	·1336	·0571	·0016	70·	30·	·8

The researches of Becker, Deutschmann, Cohn, Laptschinsky, Priestley Smith, and others are briefly reviewed. Due caution is observed in considering the results of the analyses as rather contributory and suggestive than final and conclusive.

Attention is drawn to the increasing weight generally observed with age, and to the small range of the ratio of solids and water in healthy lenses, being fairly constant at all ages. Comparison is made with similar analyses of ten cataractous lenses, and conclusions drawn as to the nature of the change; and certain bearings of the facts ascertained upon the nature of Presbyopia, Hypermetropia acquisita, and Glaucoma, and the operation for cataract are pointed out.

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8. *Indications for the Cure of Infectious Diseases.* *By* E. H. HANKIN, *B.A., from the Cambridge Pathological Laboratory.*

Koch's discovery of the tubercle bacillus, and the great advance in our knowledge of the bacteriology of disease to which this gave rise, not only attracted great attention in the scientific world, but produced the hope that the cure of infectious diseases might be obtained simply by the employment of antiseptics. The numerous attempts that were made to cure consumption and other diseases by means of antiseptics, whether given by inhalation or otherwise, have practically resulted in failure. All substances hitherto discovered that have the power of destroying microbes are also poisons to the higher animals. If they are administered to the animals in quantities necessary to destroy the pathogenic microbes, they will also kill the infected animal.

The researches of Behring, Nissen, Bouchard, and others have shown that in an animal that is naturally refractory to a disease, or which has been made artificially immune against it, there is present some unknown substance which has, to adapt Bouchard's term, a bactericidal action on the microbe in question. In other words, there is present a natural antiseptic of unknown nature in quantities sufficient to prevent the growth of the pathogenic microbe, but yet without affecting the general health of the animal. Is it not conceivable that by injecting this substance into animals we might obtain better results in the way of curing infectious diseases than have been obtained by means of such unnatural antiseptics (if the term may be used) as mercuric chloride or eucalyptol?

For some time past the author has attempted to discover the nature of these substances, and it appears to him that his results are sufficiently interesting to be communicated. In a conversation that he had with Dr. Lauder Brunton some years ago, he suggested to him that possibly the organism protects, or tries to protect, itself from microbes by means of ferments. Just as an amœba seems to secrete a ferment to digest a microbe that it has swallowed, so, possibly, the cells of the higher animals secrete ferments to protect themselves against pathogenic microbes. If this be so, it becomes of great importance to know what is the ferment in question, and he thought it would be worth while to see whether any of the ferments that the animal body is known to produce could exert any influence on the course of the disease. His earlier results have appeared in a paper read before the Cambridge Philosophical Society. By injection of minute quantities of pepsin and trypsin into rabbits twenty-four hours after they had been inoculated with anthrax, he found that the course of the disease could be in many cases modified in a remarkable manner. In one case a rabbit that had been inoculated for him by Professor Koch with virulent anthrax completely recovered. Twenty-four hours after its inoculation he injected 2½ c.c. of a ·05 per cent. solution of trypsin into its lateral ear vein. The same day its temperature was found to be 37°·4, that is to say, nearly 2½ degrees below the normal temperature of a rabbit. It remained at approximately this low figure for some days, showing a very gradual rise, and only on the sixth day after inoculation had it reached 38°. From this point it rapidly rose, till on the eleventh day after inoculation it was 40°·1. On the twelfth day it stood at 40·05, when observation of its temperature was discontinued. Another interesting point about the case was the appearance of pus at the seat of inoculation. On the eighth day after the experiment began, a small hard tumour, about half an inch in diameter, was found at the seat of inoculation. On the thirteenth day a second large tumour appeared in front of the former. This gradually increased in size, and was found to contain caseating pus. About a week later no further increase in size could be noted. The animal appeared to be emaciated, but after some weeks was strong and fat. Although he was not so successful with the other twelve rabbits that he had used in this research, they often exhibited symptoms of great interest. In one case the rabbit lived for thirteen days; in most cases, however, they died in 60–70 hours after inoculation, or perhaps lived no longer than the control-rabbit. After treatment with either pepsin or trypsin the following peculiar appearances could be observed in their spleens:

(1) Whereas in the control-rabbit, as was usual with virulent anthrax, the bacilli were seen as short rods, in the research animals the bacilli were often to be found arranged in the long chains so characteristic of attenuated anthrax.

(2) Whereas in the control-rabbit phagocytes containing bacilli can only very rarely be found, in the rabbits treated with pepsin and trypsin, in some cases, spleen-phagocytes containing bacilli are particularly numerous.

(3) The chains of bacilli sometimes showed signs of degeneration, staining very irregularly, some joints being stained, others remaining nearly colourless. In other experiments that he has performed since, the author has seen degenerated bacilli at the seat of inoculation, but nowhere else.

Another interesting point is that rabbits whose life is prolonged by treatment with ferment will occasionally show diarrhœa for some days before their death. The author has only noticed this in two or three cases.

With regard to these facts, it may be noted that the attenuated appearance of the bacilli, the signs of phagocytosis, the elongation of the incubation period, and the diarrhœa, can all be regarded as indications that the power the animal possesses of resisting the onset of the disease has been increased by the injection of ferments. On the other hand, the striking irregularity in the results must be noticed. Often an animal treated with pepsin or trypsin will die as soon as, or even sooner than, the control-animal. The bacilli in its spleen may be not longer, but shorter than usual, and phagocytosis, and the enlargement of the spleen that generally accompanies it, may be completely absent. It is a general rule that opposing forces produce irregular results; and the widely varying effects of ferment injection led me to look for some conflicting tendencies. Possibly, on the one hand, the ferment was harmful to the anthrax bacilli; but, on the other hand, also harmful to their host, and so lowered its bactericidal power. He attempted to decide whether this was the explanation of his results in the following way. So far as is known, acquired tolerance can be obtained far more readily against poisonous proteids than against any other kind of poison. Since pepsin and trypsin either are proteid in nature, or appear to be more allied to proteids than to any other class of bodies, would it not be possible to obtain an acquired tolerance on the part of the rabbit against them, leaving unaffected their action on the later-arriving anthrax bacilli? The first experiment to test this had a result apparently favourable to the idea. On April 6 three rabbits, A, B, and C, received 4, 3, and 1½ c.c. respectively of a ·08 per cent. solution of trypsin.[1] The next day 5, 1, and 1½ c.c. respectively of a ·1 per cent. solution were injected into each rabbit, and on April 8 they received respectively 4, 2, and 2 c.c. On April 7 they were all inoculated with anthrax. A control-rabbit was also inoculated, and succumbed after about sixty hours. He has in his notes that the anthrax culture was 'deuxième vaccin,' but as it had been repeatedly transmitted from culture to culture (on agar-agar) for at least eight months, and generally killed rabbits in thirty-six to forty-eight hours, without any doubt it had in some measure, at all events, recovered its virulence. All three rabbits had diarrhœa. A, that is to say the rabbit which had most trypsin, died a week after the anthrax inoculation. The other two recovered. B had diarrhœa for some days, but this had vanished, and its temperature was normal on April 18. At this date C's temperature was 40°·4, and it still had diarrhœa, which only dis-

[1] The trypsin employed was obtained from Schering's Grüne Apotheke, Berlin.

appeared by the end of the month. On May 1, B, which seemed perfectly healthy, was re-inoculated with anthrax, and though it died at the same time as a control-guinea-pig, namely, thirty-six hours, a large number of phagocytes containing bacilli could be found in its spleen. Rabbit C remained emaciated. It seemed to have a slight paralysis of the hind legs, and was killed on May 2. The spleen showed many macrophages containing pigment granules. The supra-renal capsules were enlarged, but no cavity was visible in them. The psoas muscle was reduced almost to a film. In another experiment, in which pepsin was employed in 1 per cent. solution in repeated and gradually increasing doses, all three rabbits died within thirty-six hours after inoculation; but many splenic phagocytes crowded with bacilli were seen. In other respects the appearances were those of typical anthrax. In a third experiment six rabbits each received 1–2 c.c. doses of ·2 per cent. trypsin on two successive days. The next day they were inoculated with anthrax, and received 1–3 c.c. each of a 1 per cent. solution of trypsin. Of these none lived longer than sixty hours (the control had died in thirty-six hours). In all except one the bacilli were, for the most part, in unusually long chains, and often either in, or apparently growing out of, phagocytes.

In a fourth experiment five rabbits received slightly smaller doses of trypsin, and died of typical anthrax at the same time as the control.

It is obvious that these experiments give but a meagre support to the suggestion that the supposed harmful effect of the ferment (as regards the system) can be obviated by producing an acquired tolerance against it, and, considering the small number of his experiments, and the complicated nature of the factors involved, the author is loth to draw any positive conclusion. But the further question arises, viz. how, when the ferment does have any action at all, does it produce its effect on the course of the disease? He set out with the assumption that the ferments might exert a direct bactericidal action on the microbe. But, considering the minute quantities of ferment necessary to produce the results described above, and the complete absence of evidence that pepsin and trypsin have any direct antiseptic action, it seems hardly likely that this simple explanation is the true one. Another line of work that he has recently been engaged in has, however, led him to another more probable explanation of these results of ferment injection. In a paper that he read last May to the Royal Society, he described a proteid body, which he has extracted from the lymphatic glands and spleen of various animals, which has the power of destroying anthrax bacilli. Since publishing this paper he has found that a bacteria-killing substance can be extracted from the blood of febrile animals. For example, a rabbit was inoculated with anthrax; twenty-four hours later, when its temperature had risen to 40°·4, it was decapitated and the blood allowed to run into alcohol. A watery extract of the precipitated blood showed bacteria-killing powers. A watery extract of the blood of a normal rabbit similarly treated showed, on the contrary, no distinct bactericidal action. This fact indicates that we are dealing with one of the essential elements of the febrile reaction. Probably the substance obtained from the febrile blood is identical with the bacteria-killing globulin that he obtained from the cells of the spleen, and, if this be so, it seems to deserve the name that he has already given it of a 'defensive proteid.' In other words, the system, when menaced by the attack of a pathogenic microbe, is protected by the appearance of this substance in the circulation. Now, a paper on the physiological action of ferments has recently appeared,[1] in which it is shown that these substances, when injected into the blood, cause fever, and a diminution in the number of the white blood-corpuscles. The author of this paper believes that these white blood-corpuscles break up and liberate fibrin ferment. To this he ascribes the increased coagulability of the blood which he finds to be present after injection of small doses of various ferments. It is conceivable that the defensive proteid that the author has discovered would also be thrown into the circulation on the injection of ferments. Here, then, we have a possible explanation of the mode of action of trypsin and pepsin in modifying the anthrax attack.

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[1] Hildebrandt, Virchow's *Archives*, vol. ii. p. 1.

9. *Experiments with Drugs as a Question of Science.*[1] *By* WILLIAM SHARP, *F.R.S.*

At the meeting of the British Association for the Advancement of Science, held at Nottingham in 1866, a paper was read 'On the Physiological Action of Medicines,' the subject being the action of medicines when taken in *health*.

The experiments already tried were referred to, and suggestions were made relative to further experiments (1) on the objects to be pursued, (2) on the mode of proceeding, (3) on the utilisation of the results.

As these experiments have been continued by the author since the date of that paper, now twenty-four years ago, it seems to be a duty to make some report to the Association. On the present occasion this shall be confined to the conclusions arrived at on one part of the question only. To attempt more would occupy too much of the time of this meeting.

Perhaps the Section may be reminded that the primary object of these experiments is to answer this question in science: What is the action of the substances called drugs on the living body of man?

It is evident that experiments made in order to discover this action must be made on persons in *health*; for, when drugs are given to the sick, the complications arising from the existing disorder make it difficult, and often impossible, to distinguish the action of the drug from the effects of the disease.

Everyone is aware that this enquiry is comparatively a new one, and that as yet little is known of it.

The conclusions arrived at, which are to be laid before the meeting to-day, are the results of experiments with *different quantities of the same drug.*

They may be briefly expressed as follows:—

1. The smallest doses used in these experiments have power to act upon the living human body.

2. The commonly received opinion that the actions of drugs are simply increased in degree and not altered in character by increasing the dose is an error.

3. The actions of doses are sufficiently distinct to admit of classification.

4. This classification has two divisions. The first contains groups of doses arranged as they act upon the same person. The second contains groups of doses arranged as they act upon different persons.

5. Experiments show that several small doses act upon the same person nearly in the same manner; these, therefore, form a group. And there are several larger doses which act differently from the first group, but in regard to themselves nearly in the same manner; these, therefore, form another group. This is the first division.

6. When not only the quantity of the drug but also the person experimented upon is varied, a complication is introduced, owing to the varying sensitiveness of different persons; nevertheless a succession of groups of doses may still be observed. These groups differ from, and often overlap, those of the first series. This is the second division.

7. Each of the groups of doses in either division has characteristic actions, in kind or in degree, which distinguish them from the others.

8. The actions of a group of certain small doses are directly contrary to the actions of another group of certain larger doses. This conclusion is so clearly established as applicable to all drugs, and is so new, that the author has felt it necessary to give it a name, and has called it *Antipraxy, i.e.,* contrary action.

9. There is a group of intermediate doses, between these contrary-acting groups, which has both actions in succession.

10. There is a group of still larger doses, which have the same actions as the smallest ones, but differ from them in degree; they act more violently, and their action is accompanied with more or less serious complication.

11. There are yet larger doses, which again act in the contrary direction.

12. The experiments already tried seem to indicate that between every two

[1] The Paper, with a Supplement, will be published by Messrs. Bell & Sons as Essay LVIII.

single-action groups there is a group of intermediate doses having the double action.

13. It would appear, therefore, that four groups of gradually increasing doses form a *cycle*, which is then repeated.

14. These results of experiments are *facts*. Theoretical explanations of them are to be rejected, such explanations being hindrances, not helps, in our search after truth. The facts themselves, without any explanation of them, admit of being made practically useful in prescribing medicines for the sick.

For details of many of these experiments the author refers to 'Essay LVII., A Study of Doses,' published by Messrs. George Bell and Sons, London, 1890.

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10. *On the Incubation of Snakes' Eggs.*[1] *By* Dr. WALTER SIBLEY.

After giving a short review of the literature and referring to the observations of Valenciennes, Sclater, and Forbes on the increase of the temperature in the incubating female Python, the author went on to describe a series of experiments he had recently made on the eggs of the common English snake, in subjecting them to various degrees of temperature and moisture. Some eggs were placed in an incubator at a temperature of 90° F. and others were kept in a room of a temperature of 63° F., and the respective dates of hatching given. Some of the eggs which were kept in the room were one night placed in a low temperature of 35° F., and many of these afterwards hatched. The author then proceeded to describe in detail the process of hatching. At first a slit, usually soon becoming V-shaped, appeared at the highest part of the egg-shell, whether the egg was placed on its side or on one end. At the crack the snout of the young reptile appeared. Then after a time the head was protruded, and often it remained out of the shell for some hours before the body and tail were hatched; if disturbed the head was again withdrawn into the shell. The author had seen the fully hatched young snakes return into their shells when alarmed. The appearances of the snakes when first hatched were finally described. They were very smooth and velvety to the touch, the yellow ring beautifully marked from the first, and the eyes open, but often there was some opacity about the cornea, which disappeared in the course of a few hours. In length they were about six inches, and in weight about eighty grains. The characteristic hissing sound produced, when disturbed, was audible within the first few days.

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11. *Some of the probable causes of Variation in the Eggs of Birds.* *By* H. B. HEWETSON.

MONDAY, SEPTEMBER 8.

The following Papers were read:—

1. *On the Development of the Head of the Fly of Chironomus.* *By* Professor L. C. MIALL, *F.L.S.*, *and* A. HAMMOND.

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2. *On the Structure of Muscular Fibre as demonstrated by 'Castings' taken in Collodium.* *By* J. B. HAYCRAFT.

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3. *Notes on the Anatomy and Morphology of the* Cystidea. *By* P. H. CARPENTER, *F.R.S.*—See p. 821.

[1] Published *in extenso* in *Nature*, 1890.

4. *On Variability in Development. By* Professor A. Milnes Marshall, *F.R.S., and* E. J. Bles.

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5. *On Secreting Cells.*[1] *By* Professor G. Gilson.

During some years past the author has been engaged in studying the structure and mode of action of secreting cells. For, with respect to the question of secretion, it seems to him that, though an immense number of works have been published on the subject, there remains still much that is unknown.

A complete and adequate summary of these still unfinished researches is not given, the author confining himself to a very short account of the principal results obtained by describing in a few words several of the most interesting objects which he has met with in different groups of beings.

(1) *The silk-producing cells of the Lepidoptera.*—The author made a short communication on the secretion of these cells last year, at the Newcastle meeting. On that occasion he pointed out that these cells are perfectly closed elements, their inner surface being covered with a thin but very strong and finely striated membrane.

The silk substance, produced within the protoplasm, passes from it into the cavity of the organ, not by forcing its way violently through this membrane, but by filtering through it slowly and regularly.

(2) *The epithelial cells with a striated plate.*—These cells are well known to biological students; but many are not aware of the degree of development to which this striated plate may attain in several inferior animals, especially in the arthropods.

There exist two kinds of striated plates, which shall be distinguished as the *open* and the *closed.*

The former is composed of tiny rods only, very regularly disposed on the inner surface of the cell, and entirely separated from each other. The cells bearing this plate resemble so closely ciliated cells that one is apt to mistake one for the other; but in the striated plate the tiny rods never move, and so in spite of their likeness and morphological homology they are not real cilia.

These motionless rods are ordinarily glued together by a sticky matter, which conceals them more or less from sight. But often, as happens particularly during digestion, they are entirely free from this matter, and then they appear exactly like cilia. It is thus scarcely necessary to say that there is no question of tubes piercing the plate, and that therefore Professor Leydig's denomination, 'Porenkanälen,' is by no means to be retained with respect to the striæ.

Very striking instances of this kind of plate are found in the intestine and Malpighian tubes of insects, myriapods, and crustaceans. In vertebrates this plate is well known in the digestive organs. It exists also in the kidney, for the so-called 'Heidenhain's rods' are nothing else than the rods of an open striated plate covering certain cells of the urinary tubes.

In the closed plate, on the contrary, the rods or cilia are united to each other by transverse fibres, and its external surface seems to be closed with an extremely thin and apparently structureless membrane. Its structure does not differ from that of many other cellular membranes.

Certain parts of the intestine of insects and crustaceans are covered with these *closed* plates; but in certain species, for instance in the Oniscus, the digestive tube does not contain a single open plate.

(3) *The silk-producing cells of Tenthredo.*—The silk-producing gland of this species differs notably from that of the silkworm. It consists of an epithelial tube with many large appendicular cells. These are the producing elements. They are packed with silk spherules that fuse together into a more considerable mass, which glides directly into the tube through a yawning aperture. In this case the secreted substance does not filter through a membrane.

[1] This work when published *in extenso* will contain a summary and a criticism of the literature of the subject.

(4) *The bursting cells.*—Many well-known epithelial cells are not essentially different from the silk-producing cells of Tenthredo. For example, the so-called 'caliciform cells' and other elements of the same kind.

These cells are ordinarily furnished either with real vibrating cilia, or with a striated plate.

They work in the same way as the cells with a striated plate during the first part of their life; but the secreted product soon accumulates within their protoplasm in the form of one or more small masses. These increase gradually in size, and finally cause the cell membrane to burst. Their substance begins then to glide more or less rapidly into the cavity of the organ.

The author has observed in certain cases, but not very often, for instance in the *Triton cristatus*, that this gliding mass was divided from the protoplasm, not by a thin and apparently structureless membrane, but by a striated zone entirely similar to the plate, of which it was the continuation. In this case he is inclined to think that the wall of the small cavity, as well as the striated plate itself, continues to allow the permeation of the secreted fluid.

The intestinal villosities of certain coleoptera, for instance, the *Cephalotes*, contain in their middle part a series of transparent cells entirely different from the other epithelial cells. The nearer they lie to the digestive cavity, the larger they are. The last and largest one is often found in a state of destruction, which indicates that it has burst and given forth its contents.

Another kind of cell which does not exactly burst is found in the intestine of many insects and myriapods. In these elements the secretion accumulates at the extremity of the cell until it forms there a considerable protuberance. These protuberances become pediculated, and finally they fall off into the tube. Of course, they themselves are destroyed later, bursting and setting free their contents.

These facts and many others which have not been mentioned induce the author to adopt the following view on secretion:—

All the cases of cellular secretion are reduced to two general processes: the *regular filtration* and the *direct pouring* out.

In the first process the substance permeates more or less rapidly through a filtering membrane. A thin and apparently structureless membrane is found ordinarily when the secretion is active and perfectly liquid, as, for instance, the secretion of the bile. A striated plate is often connected with the slower production of a more or less viscous substance. A viscous substance may certainly filter through the striated plate, and this plate, perhaps, plays then the part of an accumulating apparatus, out of which the substance may be cast quickly when a large supply is wanted.

In the second process the substance does not pass through a filtering membrane, but is cast out directly. The excess of production over elimination causes the substance at first to accumulate in a perceptible manner within the protoplasm, and produces subsequently the opening or bursting of the cell. The first process seems to be the primitive one, the most regular, and, in a certain sense, might be called the most physiological process of cellular secretion.

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6. *On the Regeneration of Lost Parts in Polyzoa.* *By* SIDNEY F. HARMER, *M.A.*, *B.Sc.*

It has long been known that, in the great majority of *Polyzoa*, a remarkable process takes place, by which, in each individual unit of the colony, the polypide degenerates from time to time, and becomes a 'brown body.' A new polypide is then formed as an internal bud from some part of the old zoœcium, and soon becomes the functional digestive system of the latter.

In *Crisia*, one of the *Cyclostomata*, not only are the polypides periodically renewed, but the zoœcia themselves, or even whole branches of the colony, may be regenerated. This regeneration of parts other than the polypides is a subject which has hitherto attracted comparatively little attention.

In the early spring, submerged stones from suitable localities may be found to be covered by the discoloured stumps of colonies of *Crisia* which grew in the preceding year; and it may be seen that here and there a young zooecium or branch, noticeable from its pure white colour, is being budded out from an apparently dead stump.

This regenerative process may take place in various ways. For instance, an old zooecium may form a fresh aperture, and again become tenanted by a polypide; or it may grow out into a rootlet or into a growing-point, which will, in course of time, give rise to a complex branch. If a rootlet is formed, it may acquire a considerable length, and then either give rise to a fresh stem as a lateral branch, or it may after a time take on the characters of a growing-point, so that the new stem is the direct prolongation of what was at first an ordinary rootlet. It is well known that the rootlets formed during the normal life of the colony have also this power of giving rise to fresh stems.

More commonly the new branches formed from the stumps of old colonies are developed from the old joints; sometimes from the lateral joints, at the points where old branches have been thrown off; and sometimes from the axial joints, at the points where old axial internodes have been lost. Or if the fracture of a branch has taken place across an internode, the broken surface of the internode has the power of developing a fresh growing-point, which ultimately gives rise to a new branch.

In certain species of *Crisia* the aperture of the zooecium has the form of a long tube. In the lower parts of the colony it is generally found that these tubular portions have been lost, and that the part of the zooecium which is left behind is protected from further injury by the development of a calcareous diaphragm, which prevents foreign bodies from falling into the cavity of the zooecium. Diaphragms of this nature have been described in a considerable number of *Cyclostomata*. If a *Crisia* colony be stained and made transparent, it is found that a zooecium which possesses a diaphragm contains a brown body, but no functional polypide. Here and there it will be noticed that a polypide-bud is being developed below the diaphragm. With the further development of this bud, the diaphragm is absorbed, the mouth of the zooecium again growing out into a long tube, which terminates in the aperture from which the tentacles of the now functional polypide can be protruded.

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7. *On the Meaning of the Ampullæ in* Millepora murrayi (*Quelch*). *By* S. J. Hickson, *M.A.*, *D.Sc.*

In a letter published in 'Nature' in 1884, Quelch called the attention of naturalists to the presence of certain ampullæ in a new species of *Millepora*, which he called *Millepora murrayi*. At the time this letter was written the gonads of *Millepora* were quite unknown, and Quelch naturally supposed that his discovery indicated that the sexual products of *Millepora* were similar in origin and growth to those of the *Stylasteridæ*, where the male and female products are contained in the large and well-known ampullæ that have been observed by many naturalists.

Upon examining the structure of *Millepora plicata*, the author found that the ova are extremely minute, and the sperm sacs borne by the dactylozooids, an arrangement quite distinct from that of any known *Stylasterid*. No signs of anything corresponding to ampullæ were to be seen.

He was very much puzzled, then, to account for the so-called ampullæ of *M. murrayi*.

Early this year Professor Haddon placed in his hands some specimens of a *Millepora* collected by him in Torres Straits. As the specimens are fragmentary, it is difficult to say whether they are quite identical with the species described by Quelch from Samboangan. At any rate, they possess some of the most marked characteristics of Quelch's species, and—a fact of prime importance in connection with the subject in hand—they are provided with ampullæ.

These ampullæ do not contain ova or embryos in any stage, but modified dactylozooids bearing very large sperm sacs only

The eggs of *Millepora murrayi* are quite minute, as in *Millepora plicata*. They are found in the same positions, and they pass through similar, if not identical, stages in their maturation and development.

The most important conclusion to be drawn from this investigation is that as regards the position and general character of the gonads *Millepora* is not related to any of the known *Stylasteridæ.*

It may be added further, that the more completely the anatomy of *Millepora* is known, the more sharply is the line defined that separates *Millepora* from all the other *Hydrocorallinæ.*

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8. *On the male Gonangia of* Distichopora *and* Allopora. *By* S. J. Hickson, *M.A., D.Sc.*

The author can find no reference by any previous writer to the male sporosacs of *Distichopora.*

Those of *Allopora* were discovered and described by Moseley.

In *Allopora* the sperm sacs lie between the endoderm and ectoderm of club-shaped, cæcal diverticula of the canal system, that are given off some distance below the surface of the corallum. They are not visible, therefore, in specimens previous to decalcification.

In *Distichopora* these diverticula are not so long and prominent. They are usually grouped together in threes and fours, and lie immediately beneath the surface, so that they are when mature quite visible before decalcification. Moseley calls attention to tail-like processes on the distal extremity of the sperm sacs in *Sporadopora.* These are, when the spermatozoa are mature, two cell-layered tubes opening to the exterior for the escape of the spermatozoa. Similar structures occur in *Distichopora,* but they are not so long, as the ampullæ are more superficial.

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9. *On the Tracheal Occlusor Apparatus in Insecta.* *By* Professor A. Denny.

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10. *The Life-History of the Hessian Fly,* Cecidomyia Destructor (*Say*). *By* F. Enock., *F.E.S.*

Though nearly a hundred papers of various lengths have been written by American, English, German, and Russian entomologists since the Hessian Fly first made its appearance in Long Island about the year 1778, few of the authors have done much else than copy each other's accounts, showing that their observations have not been made in the field of Nature; and it is only by the most careful and patient watching that we can collect the various links required to form a complete life-history.

In a brief abstract on such a subject as the life-history of so important an insect as the Hessian Fly it is impossible to do anything like justice to it or give more than a few facts.

The Hessian Fly generally makes its appearance towards the end of April, continuing through May, June, and a considerable part of July, the main brood laying eggs in May in the ridges of the lower leaves of wheat and barley. Each female lays from 100 to 150 eggs, which hatch in four days, the young larvæ working their way down the leaf, and between the sheath and stem, until they arrive just above the joint. Here they fix themselves head downwards and towards the stem, the juices of which they imbibe, so weakening the plant that it is unable to bear the weight of the partly formed ear, the stalk bending down at the injured joint, generally stopping further development, and so impoverishing the ear that the grain does not come to perfection.

After feeding for about three weeks the larva assumes the so-called 'flax-seed' state; the outer skin gradually changes from white to chestnut colour, becoming hard and somewhat brittle. At the same time that this drying-up and change of colour has been going on a wonderful change has taken place within, the larva shrinking and becoming entirely free, though still surrounded by the hardened skin of the original larva. The mouth-organs of the internal larva are not much changed, but more invaginated, and on the second segment, immediately below the mouth, is the much-misunderstood 'anchor-process,' which has been described by our English authors as assisting the larva in obtaining its food—a most extraordinary error. Anyone taking the trouble to examine a feeding larva will see that the anchor-process is not present, it not being required during that stage.

The author has proved by the most careful observations that the use of this wonderful anchor-process is to assist the larva in its third stage to *reverse its position*, so that when the insect is matured the fly can emerge; a thing impossible for it to do did it remain in the original position occupied by the feeding larva. This reversing of position does not take place until about two weeks before the fly is fully matured. The anchor-process is really a most exquisitely formed bifid lever, with which the larva gradually works its way round within the puparium; when this is effected the change to the pupa state soon takes place, the insect emerging in two weeks. The pupa bears a very close resemblance in its details to that of the Goat Moth (*Cossus ligniperda*).

Numbers of Hessian Flies emerge in September and lay their eggs upon the self-sown barley and wheat, and where a field has been sown with clover there is always plenty of cover for the flies, and aftergrowth, upon which they quickly oviposit, the larvæ feeding up and changing to puparia before winter, the flies emerging before the clover is cut, and ready to injure the growing crops. Large numbers of puparia are always left in the stubble.

Many remedies have been tried in America for the purpose of checking the ravages of this 'pest,' but with very small success. The author does not think that anything can be done except by taking advantage of Nature's own remedy, viz. the parasites, of which there are several species.

Not a very long time ago he wrote to the 'Mark Lane Express,' suggesting the desirability and great importance of collecting and preserving the infested wheat and barley for the purpose of breeding the parasites in quantities, and then turning them down in infested districts. This proposition was met with the most extraordinary and unaccountable opposition from a writer who but a short time before had sung the praises of the parasites. The author still maintains that it *is* possible to breed these parasites in vast numbers. He has had but little leisure for doing this, and yet during the past three years he has bred over two thousand. During last June he was enabled to send over three hundred *Semiotellus nigripes* to Professor C. V. Riley, the State Entomologist at Washington, and though, owing to the heat and confinement during transit, they did not arrive so as to be of service, he expects to be able to introduce some thousands of this parasite into the United States during 1891, and anticipates that it, like other insects not indigenous to America, will increase and make its presence known and felt. There is one immense satisfaction in an endeavour to introduce such an insect into America, viz. every encouragement is given there to the study of economic entomology.

Has not the time arrived when the British Government might vote a few pounds per annum for a similar purpose, and so make the 'British Gallery' at the Natural History Museum, South Kensington, a place where farmers, and others who are not farmers, might learn something more than the mere name of an injurious insect? The very *least* that might be done would be that the Museum should possess *type* specimens of injurious insects, and certainly of such parasites as prey upon them. It is a lamentable fact that amid the numberless named insects in the collections there is not a single specimen of the American parasites of the Hessian Fly.

As to those faint-hearted entomologists who assert that such a suggestion concerning the breeding of parasites in number is not practicable, the author calls their attention to the U.S.A. report on Mr. Koebele's journey to Australia in search of the 'natural enemy' of the orange scale, which he obtained in hundreds—sent home, where it was reared in *thousands* and distributed to the almost eaten-out orange-growers, and with the result that the pest has been cleared off the face of the country. This enterprise will be a lasting monument to Professor C. V. Riley, who does NOT believe in such an expression as 'It can't be done.'

11. *Notes on the Spawning of the Anguillæ. By the* Rev. J. E. Fraser.

The hatchery was in an old stream which has not been known to run dry, and about a dozen yards from the lake—Lochness—into which the burn flows. The time or season was early in May and for three weeks in June. The stream was shaded at the hatchery by alder trees. The establishment consisted of six inhabitants—four males and two females. The act of reproduction was as follows. The female adhered to or attached her head (mouth) to a firm stone or pebble, then the male fixed himself to her head by suction or pressure, and put one coil of his tail around the middle of her body, then slid or glided down that section, until it reached the desired spot. From the moment of connection there is a very lively play of tails, and so strong as to disturb the coarse sand and ova recently deposited. The female apparently passes four or five eggs simultaneously with the withdrawal of the male organ. The ova, as a rule, fell to the bottom, and lay on the coarse sand or pebbles as small white, globular bodies. When the reproductive act was a little stronger than the normal excitement, the ova ejected and those deposited were carried a little way down stream, but only to sink to the bed of the burn. After this observation had gone on for a time, two and even three males were seen to fasten on the female, one on each side and a third on the back, and the whole three would endeavour to impregnate her at the same time. By means of a walking-stick, two of the eels were jerked out of the water. One wriggled back, the other was brought back after a dry bath of five minutes. It is remarkable that the two thrown out were evidently females. This conclusion is arrived at from the fact that no reproductive acts were observed among the remainder, who kept about the place for a fortnight and then disappeared. Twenty days after, the new hatchery of six (four males and two females) was discovered higher up stream in complete working order, but operations were largely conducted under a flat stone, which was removed without any apparent alarm. The processes were as already described, and connection took place every three minutes and lasted about six seconds. It may be mentioned that the male organ was always unsheathed. The day after removing the stone there was no trace of eels or ova. Observation was very difficult, on account of the similarity of size and constant sameness of motion and contiguity of the lively creatures.

It is very probable that the male by passing a coil of his tail end around the female not merely keeps her *in situ*, but likewise presses the ovarium, and thus brings its more matured contents into immediate contact with the fertilising fluid.

TUESDAY, SEPTEMBER 9.

The following Papers were read :—

1. *On the Power of certain Bacteria to form Organic Compounds from Inorganic Matter. By* R. Warington, *F.R.S.*

The experiments of Warington, Munro, Frankland, and Winogradsky have shown that the nitrifying organism can be easily propagated, and will discharge its functions actively in ammoniacal cultures to which no organic matter has been added. From such cultures other similar inorganic solutions may be seeded, and there is apparently no limit to the series of cultures which may be thus obtained. With the nitrifying organism some other species of bacteria may be associated.

The subject has recently been rigorously investigated by Winogradsky. Using vessels and solutions specially purified from organic matter, he finds that under such conditions the nitrifying organism increases abundantly and discharges its function with unabated vigour. He has further, in four cases, made actual determinations of the carbon as organic matter formed in solutions during nitrification, and finds this to be a very appreciable quantity.

The formation of organic matter from ammonium carbonate by an organism destitute of chlorophyll, and growing most freely in darkness, is a fact of the highest scientific interest. Winogradsky suggests that an amide is probably the compound first produced. The formation of an amide, and still more the formation of albumin or cellulose from ammonium carbonate, is a very improbable chemical reaction, as it must be attended with a large absorption of energy. If, however, we may regard the molecule of ammonium carbonate existing in solution as a large one, and that the oxidation of the ammonia to nitrous or nitric acid proceeds at the same time as the formation of organic matter, the action becomes possible, the large liberation of energy during the oxidation of the ammonia counterbalancing the absorption of energy during the formation of organic matter.

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2. *Notes on Phylloglossum.* *By* Professor F. O. Bower.

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3. *On the Question of the Phylogeny of Ferns.* *By* Professor F. O. Bower.

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4. *On Hybrids and their Parents.* *By* Dr. J. M. Macfarlane.

The author stated that about 2,000 hybrid plants had been recorded up to 1881 and that since then the number had been nearly doubled. While Kölreuter and Gaertner had won for themselves lasting honour by conducting laborious and careful experimental crosses, the first who attempted to compare minutely a hybrid with its parents was the late Professor Henslow of Cambridge. Other observers followed, but no attempt had been made to observe the individual cells of which plants are built up.

Proceeding on this line of inquiry, Dr. Macfarlane stated that he found hybrid plants to reproduce, in a blended manner, the structural peculiarities of both parents. Selecting several well-known hybrids, he showed that alike in the vegetative and reproductive parts, the number of cells in a given area, the shape, size, and contents of these, and even their growth, to give a certain position to the organs of which they form the units, was intermediate in the hybrid between the parents.

Reference was then made to the remarkable Adam's Laburnum (*Cytisus Adami*), which was produced near Paris in 1825 as a graft hybrid, and was now to be found in gardens and shrubberies throughout our country. This produces on some parts of the tree branches bearing yellow flowers, exactly like the stock-parent—the common Laburnum, or other small tuft-like growths with purple flowers, as in the purple Laburnum, and again branches with flowers intermediate in size and colour. From microscopic examination it was proved that such a graft hybrid as this differed from seed hybrids in showing largely a mixture of tissue masses instead of a blending of cell characters.

The author pointed out how investigations such as these might aid in determining the relation of offspring to parents, the laws which govern the production of hybrids, and the possible value of hybrids in the origin of species. He also insisted on the need for microscopic comparison in the determination of the affinity of species from an evolutionary standpoint, and in conclusion asked zoologists and delegates from local Natural History Societies to help forward the further study of this extremely wide and interesting branch of inquiry.

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5. *Dehiscence of Fruit of* Ecballium elaterium. *By* Professor T. Johnson, *B.Sc., F.L.S.*

The author has examined the violent mode of dehiscence of the fruit of *Ecballium elaterium*, to see how it compared with that of the parasitic phanerogam *Arceuthobium oxycedri*, previously investigated. In both cases dehiscence is due to rupture under pressure of a basal zone of meristematic tissue, the fruit falling off and the seeds or seed being jerked out. In *Ecballium* F. Hildebrandt considers the thin epicarp the main factor, and describes the diameter of the hole in the pericarp as much larger than that of the fruit-stalk. The author considers this not to be the case, and is led to regard the vascular basket-work and the thick-walled, pitted cells of mesocarp and endocarp as the chief agents. Of the many plants examined not one was found in which the stalk was not thicker than the diameter of the pericarp hole, indicating that the pericarp contracts at rupture, owing to the coming into play of the elasticity of the stretched mesocarp and endocarp. It is of interest to note that, according to Van Tieghem, *Ecballium elaterium* is the only one of the *Cucurbitaceæ* without tendrils, dissemination of seeds being thus ensured in it by the violent manner of dehiscence.

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6. *Observations on Brown and on Red Seaweeds.* *By* Professor T. Johnson, *B.Sc., F.L.S.*

(1.) *New Mode of Vegetative Reproduction in* Phæophyceæ.

The solitary or tufted hairs which give the trichothallic growth in so many brown sea-weeds are well known. The author has found that in two closely allied genera, *Punctaria* and *Asperococcus*, the tufts of hairs which, in the ordinary life of the plant, contribute to the growth of the thallus are capable of giving rise to new plants as the parent plant dies down. He has found herbarium plants, especially of *Punctaria*, with such seedlings in the herbaria of the Royal Gardens, Kew, British Museum (Natural History), and Trinity College, Dublin. The specimens are not numerous, as the plantlets occur on apparently dying plants. One specimen has the remark on the sheet, a '*P. plantaginea*, very small.' He has dredged plants bearing these plantlets several times in Cawsand Bay and other parts of Plymouth Sound. He proposes to deal at length elsewhere with the results to which this discovery has led him.

(2.) *Arthocladia villosa.*

Each compartment of the plurilocular zoosporangium of *Arthrocladia villosa* contains 4–12 zoospores, not, as figured, a single large zoospore. The zoospores are all alike, and have the general structure of a phæophycean zoospore. In using the term plurilocular zoosporangium one supposes each chamber of the sporangium to contain only one spore. One ought to regard the stalked plurilocular zoosporangium of *A. villosa* as a series of unilocular multisporous zoosporangia. The author described the attempts he had made to observe the functions of the zoospores, and also their behaviour to light.

(3.) '*Oogonia of* Cutleria multifida.'

In all the descriptions of fertilisation in the interesting group of the *Cutleriaceæ* 'the absence of signs of a nucleus in the ovum is noted,' in place of 'the ovum is said to be without a nucleus.' This is no doubt due to the dense granularity of the ovum and examination of contents by simple crushing. Investigation of ripe ova by microtome and suitable stains shows that each ovum is, as might be expected, distinctly nucleated. A renewed investigation of the maturation and mode of fertilisation of the ova of the *Cutleriaceæ* seems necessary. The author drew attention to the bearing the position of the oogonia in the *Cutleriaceæ* and the *Fucaceæ* has on the affinities of these two groups.

Specimens illustrating the above were exhibited.

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7. *On the Arrangements for recording Phenological Phenomena.* *By* G. J. Symons, *F.R.S.*

Phenological observations, which may perhaps be said to have originated with Gilbert White, although studied with care in Austria, received little attention in England until 1874, when the Royal Meteorological Society invited and obtained the assistance of Delegates from the Royal Agricultural Society, Royal Horticultural Society, Royal Botanic Society, Royal Dublin Society, and the Marlborough College Natural History Society, who held several meetings, and eventually drew up an elaborate report, which, curiously enough, upon re-examining after the lapse of sixteen years, seems to show that practically few of the Delegates approved of it, although from motives of politeness they allowed it to pass. Flowers and plants, insects, and birds were referred respectively to the Rev. T. A. Preston, Mr. McLachlan, and Professor Newton. Of plants the large number of seventy-one were recommended for observation, of insects only eight, and of birds seventeen. Mr. McLachlan, Professor Newton, Mr. Bell of Selborne, and Professor Thiselton-Dyer all expressed the opinion that the list should be kept as short as possible, and although the long list of plants was retained, it was resolved that special attention be called to fifteen out of the seventy-one, by printing their names in capitals.

The Royal Meteorological Society undertook the cost and trouble of preparing and issuing the necessary forms, and from 1875 to 1888, both inclusive, the Rev. T. A. Preston prepared and the Society printed annual reports embodying the results obtained. Mr. Preston found it impossible to continue the work, and Mr. E. Mawley took it up and prepared the report for 1889.[1]

He has, however, arrived at the same conclusion as the authorities already quoted, and his recommendation to reduce and simplify the observations has been accepted by the Council of the Royal Meteorological Society, which now desires to enlist as many observers as possible, all of whom are to work according to the form, of which copies are submitted for consideration.

With this view the Council of the Royal Meteorological Society has endeavoured to obtain the assistance of the Corresponding Societies on the British Association list, and it is with the same object that the author has asked permission to bring these few words also before this Section.

8. *On the Floral Biology of* Episcia maculata. *By* Professor F. W. Oliver.

The subject of this communication was a plant recently sent over from British Guiana to this country, and which had first flowered at Kew in the summer of 1888. It was, said the author, a climber with straggling habit, with many lurid waxen flowers two inches in length. The plant was remarkable in that its flowers were never open, but the front lobe of the corolla was from the first folded back so as absolutely to close the throat like a cork. Nevertheless all the arrangements were such as were adapted for cross fertilisation, and this by the agency of some insect. The pollen and stigma were successively matured—the pollen being shed from the anthers before the stigma was ready for fertilisation. From the relative positions of the parts, self-fertilisation was an absolute impossibility. At the base of the flower was a nectary of considerable size, which secreted a great amount of nectar into the spur of the corolla. An insect, probably a bee with a very long proboscis, visiting this flower for its honey, must be able to open the tightly fitting lid, and as it passed this organ to the nectar would remove some of the pollen, and subsequently visiting a somewhat more advanced flower would deposit some of this on the stigma. The arrangements which obtained, however, prevented the insect from depositing the pollen on the stigma of the same flower. Further, the lower portions of the stamens were modified into curious flanges which guided the proboscis to the nectar. Fruit was produced only by such flowers as were pollinated by hand. The ovaries of undisturbed flowers always died off without maturing seed. The seeds also show interesting structural peculiarities. The author considered that without doubt careful search in its native habitats would lead to the discovery of some insect at once provided with a sufficiently long proboscis and acquainted with the means of opening the lid. A parallel case was presented by Darwin years ago in the orchid *Angræcum sesquipedale,* with its immensely long

[1] Mr. Symons distributed copies of the schedule; others can be had on application to Edward Mawley, Esq., Rosebank, Berkhampstead, Herts.

nectary, for which he successfully prophesied the discovery of some moth capable of reaching the nectar. *Episcia maculata* was of additional interest to the biologist in that it was protected from the ravages of unbidden guests, which would be quite unable to ensure its fertilisation. The calyx and the bracts in the neighbourhood of the flowers were covered with tiny glands, which secreted a sugary mucilage, which arrested the various creeping insects that probably infested the plant. These were content to suck up the juice, without interfering in any way with the floral mechanisms. Further, the long tube of the flower was so slippery that they would, in any case, find great difficulty in obtaining a foothold and reaching the legitimate entrance. As the plant grew at Kew large numbers of ants might be seen crawling about the calyx-segments and bracts, but they were unable to advance any further. The plant was practically unique in being at once closed and yet requiring an insect for its fertilisation.

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9. *On the Origin of Thorny Plants.* *By* Professor P. Geddes.

The author stated the customary Darwinian or natural selectionist explanation of the origin of thorns and spiny leaves. Spontaneous or indefinite variations towards spininess preserved and accumulated by the selective influence of the browsing mammals.

Apparent corroboration of this on all hands: *e.g.*, Mexican and African cycads, cretaceous and extant species. Thorny flora of goat-infested hills. Hollies, their leaves less spiny on the lofty shoots. Resultant application to difficult cases, *e.g.*, *Discaria* or *Aciphylla* of New Zealand credited to *Moa.*

Personal abandonment of these views, necessitated by widened observation of characteristic general difference in vegetative habit between allied species, thornless and thorny respectively. Consequent hypothesis of diminishing vegetativeness ('ebbing vitality') of the spiny forms, this in turn being frequently explicable by reference to unfavourable (*e.g.*, desertic) environment. This view stated as a detailed application of more general theory of constitutional or definite variation in plants and also animals (see 'Trans. Bot. Soc. Edinb.' 1886, article Variation and Selection in 'Encyc. Britannica,' and 'Life Lore,' 1888).

Criticism of this view by Mr. Wallace ('Darwinism,' p. 434) as 'glaring error' ('although the antagonism between vegetative and reproductive growth is a real agency'). Summary of Mr. Wallace's arguments.

Reply in detail, *e.g.*, Oceanic islands, and question of distribution of thorny plants generally. Appeal to distributional systematist and palæontologist; their reliance on desertic environment. Case of hawthorn, thorny and thornless species. Other rosaceæ, *e.g.*, sloe, plum, pear, roses, brambles. *Astragalus*, *Rhamnus*, *Zizyphus*, holly leaves, thistly cactuses, Euphorbias, &c. Actual evolution of thorns; the stages of morphological process illustrated (*a*) by allied species (*Vella*, *Rhamnus*, &c.), (*b*) by same individual (Hawthorn, *Discaria*, &c.).

Corresponding physiological interpretation of this: obvious gradual death from point backwards (*i.e.*, *ebbing vitality*).

Appeal to gardeners, *i.e.*, from botanist misled by (hypothetical) interpretation of non-living form to cultivator practically concerned with living habit. The constitutional view a matter of everyday experience among gardeners. Spiny plants 'are always given to die back,' 'often prune themselves,' 'are slow growers,' &c.

Appeal to actual experiment on animals. Thorny plants often uneatable to begin with, &c.

Appeal to actual utility of pruning many thorny plants, *e.g.*, hawthorn, which profits as well as suffers by the operation. Prosperity of much browsed plants, *e.g.* *grasses.*

Conclusion.—Recognition of element of truth in theory of selection by mammals, which though denied so far as its essential claim goes, that of accounting for the *origin* and accumulation of thorny character, is freely admitted as an important factor (along with desertic environment) in determining the *distribution* of thorny species. The same adjustment applicable in other phenomena commonly explained by the theory of natural selection, which thus becomes viewed as essentially an explanation fundamental as regards the facts of distribution, although inefficient as regards the origin of function or structure. The opposed theory of definite or constitutional variation along 'grooves of change,' with corresponding limitation of natural selection mainly to its *extinctive* agency, may similarly be demonstrated in other cases currently explained by natural selection only.

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10. *Note on the Occurrence in Yorkshire of* Arenaria gothica (*Fries*). *By* Professor Silvanus P. Thompson, *D.Sc.*

In June last year Mr. L. Rotheray, of Skipton, noticed, near Ribblehead station on the Midland Railway, some specimens of *Arenaria,* which on examination proved to be either *Arenaria norvegica* or *Arenaria gothica,* the two being scarcely distinguishable except by the fact that one is perennial, the other annual. It will be sufficient here to accept the name of *gothica,* leaving the question of distinction for others to decide.

The Ribblehead habitat was subsequently visited by Mr. Arnold Lees, Professor Jefferson, Mr. J. G. Baker, and other botanists. It is a matter of great regret that of the three hundred or so plants existing when it was discovered only a bare dozen have survived the greed of collectors.

A second habitat was discovered in September of the same year by Mr. Arnold Lees, being like the first a roadside spot, and not more than 300 yards from the first.

The author now announced that during the first week in August of the present year he discovered another habitat of *Arenaria gothica,* nearly three miles away from the original habitat. It is about a quarter of a mile from the nearest farmhouse, and lies nearer to the flank of Ingleborough, under Lord's Seat, at about 1,000 feet above sea-level. It is not like the original habitat, on recently made ground, but is in a place where the limestone-rock comes up flat to the surface, with a stream running over it, and a thin mossy vegetation, resembling an Alpine garden, grows in patches on the rock.

The plants growing beside the *Arenaria* are *Sagina nodosa,* two *Sedums, Euphrasia,* and *Arenaria serpyllifolia.* It certainly cannot have been introduced here. There were at least two thousand plants. During the month of August, the author twice made subsequent visits to the spot, and has compared the specimens there with specimens from the original habitat. They precisely agree in habit, but are of a more luxuriant growth.

He has also, in company with his sisters, the Misses Thompson, of Settle, searched the whole district between the original and the new habitat, but has found no *Arenaria* growing at intermediate spots.

He forbears to indicate the spot more precisely lest the same fate that has already overtaken the plants at Ribblehead should overtake those at ——.

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11. *The Flora of Victoria Park, Niagara Falls, Ontario, Canada.*[1] *By* J. Hoyes Panton, *M.A., F.G.S.*

The writer in this paper described thirteen botanical districts into which the Park may be conveniently divided for the study of its flora, and then gave a list of the plants which he has obtained from them.

The list embraces 71 orders, 261 genera, and 458 species.

The Park contains 154 acres, in the form of a narrow strip of land, extending about two miles along the river bank. This he first divides into four distinct divisions, viz.:—

1. Talus at the river's edge, derived from the disintegration of the perpendicular walls of dolomite, over 100 feet high.
2. The perpendicular rocks covered with mosses, lichens, &c., in many parts.
3. A level plain.

[1] This paper is published *in extenso* in the Report of the Park for 1889.

4. A hillside; 3 and 4 constituting the Park proper.

The whole is divided into the thirteen areas already referred to. The combination of soil, temperature, and moisture at this place was shown to be well suited to a marked variety in plant life, as well as to produce very luxuriant forms, in striking contrast to plants of the same species a few miles from the Park.

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12. *The Cytology of the Chytridian* Woronina. *By* Professor Marcus M. Hartog, *M.A., D.Sc., F.L.S.*

This parasite of Achlyr has no microsomes. There is some evidence that spore formation is not merely due to the separation of the contents of the sporange into cells; but each of the many nuclei of the sporange divides first, so that twice as many spores are formed as there were nuclei in the young sporange.

The discharging process is pushed out and formed by one of these nucleated young spores which afterward degenerates completely.

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13. *On the Acclimatisation of the Tussock Grass of the Falkland Islands. By* Professor Marcus M. Hartog, *M.A., D.Sc., F.L.S.*

This is noble grass, of the habit of the Pampas grass, and most valuable as fodder; will grow in bog land and close to the sea. It had been acclimatised many years ago in the Lewis, but appears to be failing there owing to the unchecked browsing of cattle. In introducing this plant into Ireland, in the spring of 1889, the author aimed at raising a limited number of plants from seed, growing them sufficiently wide to ensure good individual development, and increasing his supply of nursery plants by dividing them from time to time into sets. He anticipates that in a few years these plants will be propagated by sets from full-sized plants just like the Pampas grass, and suitable directly for planting out on farms. The plant does well at Cork; and at Dunmanway, in the west of the county, plants raised from seed in spring and planted out in May had in the autumn formed tussocks of eighty or more stems, each as thick as the finger at the base, and seeded, though not very freely.

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14. *On a Case of Apogamy in* Vaucheria hamata (*Vauch.*) *Lyngb. By* Thomas Hick, *B.A., B.Sc.*

The sexual reproductive organs—oogonia and antheridia—of this species of Vaucheria are found on short lateral branches of the thallus, both being found on the same branch. In the normal development of the oogonium, the apical growth is arrested, and an obliquely ovoid dilation is formed; oil, chlorophyll corpuscles, protoplasm, &c. are accumulated in this dilated part, which is finally cut off from the rest of the branch by a transverse partition. In the case of apogamy to which attention was drawn, all the steps in the development of the oogonium save the earliest were suppressed. The lateral branch ceased to grow at the apex, and the obliquely ovoid swelling occurred in the normal fashion, but there followed no aggregation of the cell contents and no formation of a transverse partition. After the rudimentary oogonium had reached the stage indicated, the apex resumed its normal growth, and grew out vegetatively into an ordinary branch of the thallus. This abnormal mode of development was met with in several instances, but it did not wholly replace the normal one. The form and the development of the antheridia were quite normal, even on the branches which bore the abnormal oogonia.

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15. *An overlooked variety of* Cynosurus cristatus (*Crested Dog's-tail-grass*). *By* W. Wilson, Jun.

The attention of the writer has been directed for some years to what he considers a variety of the above grass, which form is to be found growing occasionally in similar situations to where *Cynosurus cristatus* is found. The plants of this variety are generally smaller than those of the normal type. The culms are *generally or almost invariably* lighter green, while the flowers are white.

The author has observed these plants for several years, and has concluded that there is a natural difference, and it is not the result of any untoward accident to plants of the normal type. He proposes for it the name of *Cynosurus cristatus*, variety *Alba*.

Section E.—GEOGRAPHY.

President of the Section—Lieutenant-Colonel Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.

THURSDAY, SEPTEMBER 4.

The President delivered the following Address:—

The Mediterranean, Physical and Historical.

When the unexpected honour was proposed to me of presiding over your deliberations, I felt some embarrassment as to the subject of my address. Geography as a science, and the necessity of encouraging a more systematic study of it, had been treated in an exhaustive manner during previous meetings. The splendid discoveries of Stanley and the prolonged experiences of Emin have been amply illustrated by the personal narrative of the former. The progress of geography during the past year has been fully detailed in the annual address of the President of the Royal Geographical Society in June last; so that it would be a vain and presumptuous endeavour for me to compress these subjects into the limits of an opening address. Closely connected with them are the magnificent experiments for opening out Africa which are being made by our merchant princes, amongst whom the name of Sir William Mackinnon stands pre-eminent, and by our missionary societies of various churches, all acting cordially in unison, and sinking, in the dark continent, the differences and heartburnings which divide Christianity at home; I have thought it better, however, not to discuss matters so closely connected with political questions which have not yet passed into the realm of history.

In my perplexity I applied for the advice of one of the most experienced geographers of our Society, whose reply brought comfort to my mind. He reminded me that it was generally the custom for Presidents of Sections to select subjects with which they were best acquainted, and added: 'What more instructive and captivating subject could be wished than The Mediterranean, Physical and Historical?'

For nearly a quarter of a century I have held an official position in Algeria, and it has been my constant delight to make myself acquainted with the islands and shores of the Mediterranean, in the hope of being able to facilitate the travels of my countrymen in that beautiful part of the world.

I cannot pretend to throw much new light on the subject, and I have written so often about it already that what I have to say may strike you as a twice-told tale; nevertheless, if you will permit me to descend from the elevated platform occupied by more learned predecessors, I should like to speak to you in a familiar manner of this 'great sea,' as it is called in sacred scripture, the *Mare Internum* of the ancients, 'our sea,' *Mare nostrum*, of Pomponius Mela.

Its shores include about three million square miles of the richest country on the earth's surface, enjoying a climate where the extremes of temperature are unknown, and with every variety of scenery, but chiefly consisting of mountains and elevated plateaux. It is a well-defined region of many parts, all intimately connected with each other by their geographical character, their geological formation, their flora, fauna, and the physiognomy of the people who inhabit them. To this general statement there are two exceptions, namely, Palestine, which belongs rather to the tropical countries lying to the east of it, and so may be dismissed from our subject, and the Sahara, which stretches to the south of the Atlantic region—or region of the Atlas—but approaches the sea at the Syrtis, and again to the eastward of the Cyrenaica, and in which Egypt is merely a long oasis on either side of the Nile.

The Mediterranean region is the emblem of fertility and the cradle of civilisation, while the Sahara—Egypt, of course, excepted—is the traditional panther's skin of sand, dotted here and there with oases, but always representing sterility and barbarism. The sea is in no sense, save a political one, the limit between them; it is a mere gulf, which, now bridged by steam, rather unites than separates the two shores. Civilisation never could have existed if this inland sea had not formed the junction between the three surrounding continents, rendering the coasts of each easily accessible whilst modifying the climate of its shores.

The Atlas range is a mere continuation of the South of Europe. It is a long strip of mountain land, about 200 miles broad, covered with splendid forests, fertile valleys, and in some places arid steppes, stretching eastward from the ocean to which it has given its name. The highest point is in Morocco, forming a pendant to the Sierra Nevada of Spain; thence it runs, gradually decreasing in height, through Algeria and Tunisia, it becomes interrupted in Tripoli, and it ends in the beautiful green hills of the Cyrenaica, which must not be confounded with the oases of the Sahara, but is an island detached from the eastern spurs of the Atlas, in the ocean of the desert.

In the eastern part the flora and fauna do not essentially differ from those of Italy; in the west they resemble those of Spain; one of the noblest of the Atlantic conifers, the *Abies pinsapo*, is found also in the Iberian peninsula and nowhere else in the world, and the valuable alfa grass or esparto (*Stipa tenacissima*), from which a great part of our paper is now made, forms one of the principal articles of export from Spain, Portugal, Morocco, Algeria, Tunisia, and Tripoli. On both sides of the sea the former plant is found on the highest and most inaccessible mountains, amongst snows which last during the greater part of the year, and the latter from the sea level to an altitude of 5,000 feet, but in places where the heat and drought would kill any other plant, and in undulating land where water cannot lodge.

Of the 3,000 plants found in Algeria by far the greater number are natives of Southern Europe, and less than 100 are peculiar to the Sahara. The macchie or maquis of Algeria in no way differs from that of Corsica, Sardinia, and other places; it consists of lentisk, arbutus, myrtle, cistus, tree-heath, and other Mediterranean shrubs. If we take the commonest plant found on the southern shores of the Mediterranean, the dwarf palm (*Chamærops humilis*), we see at once how intimately connected is the whole Mediterranean region, with the exception of the localities I have before indicated. This palm still grows spontaneously in the south of Spain and in some parts of Provence, in Corsica, Sardinia, and the Tuscan Archipelago, in Calabria and the Ionian Islands, on the continent of Greece, and in several of the islands in the Levant, and it has only disappeared from other countries as the land has been brought under regular cultivation. On the other hand, it occurs neither in Palestine, Egypt, nor in the Sahara.

The presence of European birds may not prove much, but there are mammalia, fish, reptiles, and insects common to both sides of the Mediterranean. Some of the larger animals, such as the lion, panther, jackal, &c., have disappeared before the march of civilisation in the one continent, but have lingered, owing to Mohammedan barbarism, in the other. There is abundant evidence of the former existence of these and of the other large mammals, which now characterise tropical Africa, in France, Germany, and Greece; it is probable that they only migrated to their present habitat after the upheaval of the great sea which in Eocene times stretched from the Atlantic to the Indian Ocean, making Southern Africa an island continent like Australia. The original fauna of Africa, of which the lemur is the distinctive type, is still preserved in Madagascar, which then formed part of it.

The fish fauna is naturally the most conclusive evidence as to the true line of separation between Europe and Africa. We find the trout in the Atlantic region and in all the snow-fed rivers falling into the Mediterranean; in Spain, Italy, Dalmatia; it occurs in Mount Olympus, in rivers of Asia Minor, and even in the Lebanon, but nowhere in Palestine south of that range, in Egypt, or in the Sahara. This fresh-water salmonoid is not exactly the same in all these localities, but is subject to considerable variation, sometimes amounting to specific distinction. Nevertheless it is a European type found in the Atlas, and it is not till we advance into the Sahara, at Tuggurt, that we come to a purely African form in the Chromidæ, which have a wide geographical distribution, being found everywhere between that place, the Nile, and Mozambique.

The presence of newts, tailed batrachians, in every country round the Mediterranean, except again in Palestine, Egypt, and the Sahara, is another example of the continuity of the Mediterranean fauna, even though the species are not the same throughout.

The Sahara is an immense zone of desert which commences on the shores of the Atlantic Ocean, between the Canaries and Cape de Verde, and traverses the whole of North Africa, Arabia, and Persia, as far as Central Asia. The Mediterranean portion of it may be said roughly to extend between the 15th and 30th degrees of north latitude.

This was popularly supposed to have been a vast inland sea in very recent times, but the theory was supported by geological facts wrongly interpreted. It has been abundantly proved by the researches of travellers and geologists that such a sea was neither the cause nor the origin of the Libyan Desert.

Rainless and sterile regions of this nature are not peculiar to North Africa, but occur in two belts which go round the world in either hemisphere, at about similar distances north and south of the equator. These correspond in locality to the great inland drainage areas from which no water can be discharged into the ocean, and which occupy about one-fifth of the total land surface of the globe.

The African Sahara is by no means a uniform plain, but forms several distinct basins containing a considerable extent of what may almost be called mountain land. The Hoggar Mountains in the centre of the Sahara are 7,000 feet high, and are covered during three months with snow. The general average may be taken at 1,500. The physical character of the region is very varied; in some places, such as at Tiout, Moghrar, Touat, and other oases in or bordering on Morocco, there are well-watered valleys, with fine scenery and almost European vegetation, where the fruits of the North flourish side by side with the palm tree. In others there are rivers like the Oued Guir, an affluent of the Niger, which the French soldiers, who saw it in 1870, compared to the Loire. Again, as in the bed of the Oued Rir, there is a subterranean river, which gives a sufficient supply of water to make a chain of rich and well-peopled oases equal in fertility to some of the finest portions of Algeria. The greater part of the Sahara, however, is hard and undulating, cut up by dry watercourses, such as the Igharghar which descends to the Chott Melghigh, and almost entirely without animal or vegetable life.

About one-sixth of its extent consists of dunes of moving sand, a vast accumulation of detritus washed down from more northern and southern regions—perhaps during the glacial epoch—but with no indication of marine formation. These are difficult and even dangerous to traverse, but they are not entirely destitute of vegetation. Water is found at rare but well-known intervals, and there is an abundance of salsolaceous plants which serve as food for the camel. This sand is largely produced by wind action on the underlying rocks, and is not sterile in itself, it is only the want of water which makes it so. Wherever water does exist, or artesian wells are sunk, oases of great fertility never fail to follow.

Some parts of the Sahara are below the level of the sea, and here are formed what are called *chotts* or *sebkhas*, open depressions without any outlets, inundated by torrents from the southern slopes of the Atlas in winter and covered with a saline efflorescence in summer. This salt by no means proves the former existence of an inland sea; it is produced by the concentration of the natural salts, which exist in every variety of soil, washed down by winter rains, with which the salt evaporated residue of water becomes saturated.

Sometimes the drainage, instead of flooding open spaces and forming chotts, finds its way through the permeable sand till it meets impermeable strata below it, thus forming vast subterranean reservoirs where the artesian sound daily works as great miracles as did Moses' rod of yore at Meribah. I have seen a column of water thrown up into the air equal to 1,300 cubic mètres per diem; a quantity sufficient to redeem 1,800 acres of land from sterility and to irrigate 60,000 palm trees. This seems to be the true solution of the problem of an inland sea; a sea of verdure and fertility caused by the multiplication of artesian wells, which never fail to bring riches and prosperity in their train.

The climate of the Sahara is quite different from that of what I have called the Mediterranean region, where periodical rains divide the year into two seasons. Here, in many places, years elapse without a single shower; there is no refreshing dew at night, and the winds are robbed of their moisture by the immense continental extents over which they blow. There can be no doubt that it is to these meteorological, and not to geological, causes that the Sahara owes its existence.

Reclus divides the Mediterranean into two basins, which, in memory of their history, he calls the Phœnician and the Carthaginian, or the Greek and Roman seas, more generally known to us as the Eastern and Western Basins, separated by the island of Sicily.

If we examine the submarine map of the Mediterranean, we see that it must at one time have consisted of two enclosed or inland basins, like the Dead Sea. The western one is separated from the Atlantic by the Straits of Gibraltar, a shallow ridge, the deepest part of which is at its eastern extremity, averaging about 300 fathoms; while on the west, bounded by a line from Cape Spartel to Trafalgar, it varies from 50 to 200 fathoms. Fifty miles to the west of the Straits the bottom suddenly sinks down to the depths of the Atlantic, while to the east it descends to the general level of the Mediterranean, from one to two thousand fathoms.

The Western is separated from the Eastern Basin by the isthmus which extends between Cape Bon in Tunisia and Sicily, known as the 'Adventure Bank,' on which there is not more than from 30 to 250 fathoms. The depth between Italy and Sicily is insignificant, and Malta is a continuation of the latter, being only separated from it by a shallow patch of from 50 to 100 fathoms; while to the east and west of this bank the depth of the sea is very great. These shallows cut off the two basins from all but superficial communication.

The configuration of the bottom shows that the whole of this strait was at one time continuous land, affording free communication for land animals between Africa and Europe. The palæontological evidence of this is quite conclusive. In the caves and fissures of Malta, amongst river detritus, are found three species of fossil elephants, a hippopotamus, a gigantic dormouse, and other animals which could never have lived in so small an island. In Sicily, remains of the existing elephant have been found, as well as the *Elephas antiquus,* and two species of hippopotamus, while nearly all these and many other animals of African type have been found in the pliocene deposits and caverns of the Atlantic region.

The rapidity with which such a transformation might have occurred can be judged by the well-known instance of Graham's Shoal, between Sicily and the island of Pantellaria; this, owing to volcanic agency, actually rose above the water in 1832, and for a few weeks had an area of 3,240 feet in circumference and a height of 107 feet.

The submersion of this isthmus no doubt occurred when the waters of the Atlantic were introduced through the Straits of Gibraltar. The rainfall over the entire area of the Mediterranean is certainly not more than 30 inches, while the evaporation is at least twice as great; therefore, were the Straits to be once more closed, and were there no other agency for making good this deficiency, the level of the Mediterranean would sink again till its basin became restricted to an area no larger than might be necessary to equalise the amount of evaporation and precipitation. Thus not only would the strait between Sicily and Africa be again laid dry, but the Adriatic and Ægean Seas also, and a great part of the Western Basin.

The entire area of the Mediterranean and Black Seas has been estimated at upwards of a million square miles, and the volume of the rivers which are discharged into them at 226 cubic miles. All this and much more is evaporated annually. There are two constant currents passing through the Straits of Gibraltar, superimposed on each other; the upper and most copious one flows in from the Atlantic at a rate of nearly 3 miles an hour, or 140,000 cubic mètres per second, and supplies the difference between the rainfall and evaporation, while the undercurrent of warmer water, which has undergone concentration by evaporation, is continually flowing out at about half the above rate of movement, getting rid of the excess of salinity; even thus, however, leaving the Mediterranean salter than any other part of the ocean except the Red Sea.

A similar phenomenon occurs at the eastern end, where the fresher water of the Black Sea flows as a surface current through the Dardanelles, and the salter water of the Mediterranean pours in below it.

The general temperature of the Mediterranean from a depth of 50 fathoms down to the bottom is almost constantly 56°, whatever may be its surface elevation. This is a great contrast to that of the Atlantic, which at a similar depth is at least 3° colder, and which at 1,000 fathoms sinks to 40°.

This fact was of the greatest utility to Dr. Carpenter in connection with his investigations regarding currents through the Straits, enabling him to distinguish with precision between Atlantic and Mediterranean water.

For all practical purposes the Mediterranean may be accepted as being, what it is popularly supposed to be, a tideless sea, but it is not so in reality. In many places there is a distinct rise and fall, though this is more frequently due to winds and currents than to lunar attraction. At Venice there is a rise of from one to two feet in spring tides, according to the prevalence of winds up or down the Adriatic, but in that sea itself the tides are so weak that they can hardly be recognised, except during the prevalence of the Bora, our old friend *Boreas*, which generally raises a surcharge along the coast of Italy. In many straits and narrow arms of the sea there is a periodical flux and reflux, but the only place where tidal influence, properly so called, is unmistakably observed is in the Lesser Syrtis, or Gulf of Gabès; there the tide runs at the rate of 2 or 3 knots an hour, and the rise and fall varies from 3 to 8 feet. It is most marked and regular at Djerba, the Homeric island of the Lotophagi; one must be careful in landing there in a boat, so as not to be left high and dry a mile or two from the shore. Perhaps the companions of Ulysses were caught by the receding tide, and it was not only a banquet of dates, the 'honey-sweet fruit of the Lotus,' or the potent wine which is made from it, which made them 'forgetful of their homeward way.'

The Gulf of Gabès naturally calls to mind the proposals which were made a few years ago for inundating the Sahara, and so restoring to the Atlantic region the insular condition which it is alleged to have had in prehistoric times. I will not allude to the English project for introducing the waters of the Atlantic from the west coast of Africa; that does not belong to my subject. The French scheme advocated by Commandant Roudaire, and supported by M. de Lesseps, was quite as visionary and impracticable.

To the south of Algeria and Tunis there exists a great depression stretching westward from the Gulf of Gabès to a distance of about 235 miles, in which are several *chotts* or salt lakes, sometimes only marshes, and in many places covered with a saline crust strong enough to bear the passage of camels. Commandant Roudaire proposed to cut through the isthmuses which separated the various chotts, and so prepare their basins to receive the waters of the Mediterranean. This done, he intended to introduce the sea by a canal, which should have a depth of one mètre below low-water level.

This scheme was based on the assumption that the basin of the chotts had been an inland sea within historic times; that, little by little, owing to the difference between the quantity of water which entered and the amount of evaporation and absorption, this interior sea had disappeared, leaving the chotts as an evidence of the former condition of things; that, in fact, this was none other than the celebrated Lake Triton, the position of which has always been a puzzle to geographers.

This theory, however, is untenable; the Isthmus of Gabès is not a mere sandbank;

there is a band of rock between the sea and the basin of the chotts, through which the former never could have penetrated in modern times. It is much more probable that Lake Triton was the large bight between the Island of Djerba and the mainland, on the shores of which are the ruins of the ancient city of Meninx, which, to judge by the abundance of Greek marble found there, must have carried on an important commerce with the Levant.

The scheme has now been entirely abandoned; nothing but the mania for cutting through isthmuses all over the world which followed the brilliant success achieved at Suez can explain its having been started at all. Of course, no mere mechanical operation is impossible in these days, but the mind refuses to realise the possibility of vessels circulating in a region which produces nothing, or that so small a sheet of water in the immensity of the Sahara could have any appreciable effect in modifying the climate of its shores.

The Eastern Basin is much more indented and cut up into separate seas than the Western one; it was therefore better adapted for the commencement of commerce and navigation; its high mountains were landmarks for the unpractised sailor, and its numerous islands and harbours afforded shelter for his frail barque, and so facilitated communication between one point and another.

The advance of civilisation naturally took place along the axis of this sea, Phœnicia, Greece, and Italy being successively the great nurseries of human knowledge and progress. Phœnicia had the glory of opening out the path of ancient commerce, for its position in the Levant gave it a natural command of the Mediterranean, and its people sought the profits of trade from every nation which had a seaboard on the three continents washed by this sea. Phœnicia was already a nation before the Jews entered the Promised Land, and when they did so they carried on inland traffic as middlemen to the Phœnicians. Many of the commercial centres on the shores of the Mediterranean were founded before Greece and Rome acquired importance in history. Homer refers to them as daring traders nearly a thousand years before the Christian era.

For many centuries the commerce of the world was limited to the Mediterranean, and when it extended in the direction of the East it was the merchants of the Adriatic, of Genoa, and of Pisa who brought the merchandise of India, at an enormous cost, to the Mediterranean by land, and who monopolised the carrying trade by sea. It was thus that the elephant trade of India, the caravan traffic through Babylon and Palmyra, as well as the Arab *kafilehs*, became united with the occidental commerce of the Mediterranean.

As civilisation and commerce extended westwards, mariners began to overcome their dread of the vast solitudes of the ocean beyond the Pillars of Hercules, and the discovery of America by Columbus, and the circumnavigation of Africa by the Portuguese, changed entirely the current of trade as well as increased its magnitude, and so relegated the Mediterranean, which had hitherto been the central sea of human intercourse, to a position of secondary importance.

Time will not permit me to enter into further details regarding the physical geography of this region, and its history is a subject so vast that a few episodes of it are all that I can possibly attempt. It is intimately connected with that of every other country in the world, and here were successively evolved all the great dramas of the past and some of the most important events of less distant ages.

As I have already said, long before the rise of Greece and Rome its shores and islands were the seat of an advanced civilisation. Phœnicia had sent out her pacific colonies to the remotest parts, and not insignificant vestiges of their handicraft still exist to excite our wonder and admiration. We have the megalithic temples of Malta sacred to the worship of Baal, the generative god, and Ashtoreth, the conceptive goddess, of the universe. The three thousand nurhagi of Sardinia, round towers of admirable masonry, intended probably for defence in case of sudden attack, and the so-called giant graves, were as great a mystery to classical authors as they are to us at the present day. Menorca has its talayots, tumuli somewhat analogous to, but of ruder construction than, the nurhagi, more than 200 groups of which exist in various parts of the island; with these are associated subordinate constructions intended for worship; altars composed of two immense monoliths, erected in the form of a T; sacred enclosures and megalithic habitations. One type of talayot is especially remarkable, of better masonry than the others and exactly resembling inverted boats. One is tempted to believe that the Phœnicians had in view the grass habitations or *mapalia* of the Numidians described by Sallust, and had endeavoured to reproduce them in stone: *Oblonga, incurvis lateribus tecta, quasi navium carinæ sunt.*

For a long time the Phœnicians had no rivals in navigation, but subsequently the Greeks—especially the Phocians—established colonies in the Western Mediterranean, in Spain, Corsica, Sardinia, Malta, and the South of France, through the means of which they propagated not only their commerce but their arts, literature, and ideas. They introduced many valuable plants, such as the olive, thereby modifying profoundly the agriculture of the countries in which they settled. They have even left traces of their blood, and it is no doubt to this that the women of Provence owe the classical beauty of their features.

But they were eclipsed by their successors; the empire of Alexander opened out a road to India, in which, indeed, the Phœnicians had preceded him, and introduced the produce of the East into the Mediterranean, while the Tyrian colony of Carthage became the capital of another vast empire, which, from its situation, midway between the Levant and the Atlantic Ocean, enabled it to command the Mediterranean traffic.

The Carthaginians at one time ruled over territory extending along the coast from Cyrene to Numidia, besides having a considerable influence over the interior of the continent, so that the name of Africa, given to their own dominions, was gradually applied to a whole quarter of the globe. The ruling passion with the Carthaginians was love of gain, not patriotism, and their wars were largely fought with mercenaries. It was the excellence of her civil constitution which, according to Aristotle, kept in cohesion for centuries her straggling possessions. A country feebly patriotic, which entrusts her defence to foreigners, has the seeds of inevitable decay, which ripened in her struggle with Rome, despite the warlike genius of Hamilkar and the devotion of the magnanimous Hannibal. The gloomy and cruel religion of Carthage, with its human sacrifices to Moloch and its worship of Baal under the name of Melcarth, led to a criminal code of Draconic severity and alienated it from surrounding nations. When the struggle with Rome began, Carthage had no friends. The first Punic War was a contest for the possession of Sicily, whose prosperity is even now attested by the splendour of its Hellenic monuments. When Sicily was lost by the Carthaginians, so also was the dominion of the sea, which hitherto had been uncontested. The second Punic War resulted in the utter prostration of Carthage and the loss of all her possessions out of Africa, and in 201 B.C., when this war was ended, 552 years after the foundation of the city, Rome was mistress of the world.

The destruction of Carthage after the third Punic War was a heavy blow to Mediterranean commerce. It was easy for Cato to utter his stern *Delenda est Carthago*; destruction is easy, but construction is vastly more difficult. Although Augustus in his might built a new Carthage near the site of the old city, he could never attract again the trade of the Mediterranean which had been diverted into other channels. Roman supremacy was unfavourable to the growth of commerce, because, though she allowed unrestricted trade throughout her vast empire and greatly improved internal communications in the subjugated countries, Rome itself absorbed the greater part of the wealth and did not produce any commodities in return for its immense consumption, therefore Mediterranean commerce did not thrive under the Roman rule. The conquest of Carthage, Greece, Egypt and the East poured in riches to Rome, and dispensed for a time with the needs of productive industry, but formed no enduring basis of prosperity.

It is only in relation to the Mediterranean that I can refer to Roman history, but I must allude to the interesting episode in the life of Diocletian, who, after an anxious reign of twenty-one years in the eastern division of the empire, abdicated at Nicomedia and retired to his native province of Illyria. He spent the rest of his life in rural pleasures and horticulture at Salona, near which he built that splendid palace within the walls of which subsequently arose the modern city of Spalato. Nothing more interesting exists on the shores of the Mediterranean than this extraordinary edifice, perhaps the largest that ever arose at the bidding of a single man; not only vast and beautiful, but marking one of the most important epochs in the history of architecture.

Though now obstructed with a mass of narrow, tortuous streets, its salient features are distinctly visible. The great temple, probably the mausoleum of the founder, has become the cathedral, and after the Pantheon at Rome there is no finer specimen of a heathen temple turned into a Christian church. Strange it is that the tomb of him whose reign was marked by such unrelenting persecution of the Christians should have been accepted as the model of those baptisteries so commonly constructed in the following centuries.

Of Diocletian's Salona, one of the chief cities of the Roman world, but little now remains save traces of the long irregular wall; recent excavations have brought to light much that is interesting, but all of the Christian epoch, such as a large basilica which had been used as a necropolis, and a baptistery, one of those copied from the temple of Spalato, on the Mosaic pavement of which can still be read the text, *Sicut cervus desiderat ad fontes aquarum ita anima mea ad te Deus.*

The final partition of the Roman empire took place in 365; forty years later the barbarians of the North began to invade Italy and the South of Europe, and in 429 Genseric, at the head of his Vandal hordes, crossed over into Africa from Andalusia, a province which still bears their name, devastating the country as far as the Cyrenaica. He subsequently annexed the Balearic Islands, Corsica, and Sardinia, he ravaged the coasts of Italy and Sicily, and even of Greece and Illyria; but the most memorable of his exploits was the unresisted sack of Rome, whence he returned to Africa laden with treasure and bearing the Empress Eudoxia a captive in his train.

The degenerate emperors of the West were powerless to avenge this insult, but Byzantium, though at this time sinking to decay, did make a futile attempt to attack the Vandal monarch in his African stronghold. It was not, however, till 533, in the reign of Justinian, when the successors of Genseric had fallen into luxurious habits and had lost the rough valour of their ancestors, that Belisarius was able to break their power and take their last king a prisoner to Constantinople. The Vandal domination in Africa was destroyed, but that of the Byzantines was never thoroughly consolidated; it rested not on its own strength, but on the weakness of its enemies, and it was quite unable to cope with the next great wave of invasion which swept over the land, perhaps the most extraordinary event in the world's history, save only the introduction of Christianity.

In 647, twenty-seven years after the Hedjira of Mohammed, Abdulla ibn Saad started from Egypt for the conquest of Africa with an army of 40,000 men.

The expedition had two determining causes—the hope of plunder and the desire to promulgate the religion of El Islam. The sands and scorching heat of the desert, which had nearly proved fatal to the army of Cato, were no bar to the hardy Arabians and their enduring camels. The march to Tripoli was a fatiguing one, but it was successfully accomplished; the invaders did not exhaust their force in a vain effort to reduce its fortifications, but swept on over the Syrtic desert and north to the province of Africa, where, near the splendid city of Suffetula, a great battle was fought between them and the army of the Exarch Gregorius, in which the Christians were signally defeated, their leader killed, and his daughter allotted to Ibn ez-Zobair, who had slain her father.

Not only did the victorious Moslems overrun North Africa, but soon they had powerful fleets at sea which dominated the entire Mediterranean, and the emperors of the East had enough to do to protect their own capital.

Egypt, Syria, Spain, Provence, and the islands of the Mediterranean successively fell to their arms, and until they were checked at the Pyrenees by Charles Martel it seemed at one time as if the whole of Southern Europe would have been compelled to submit to the disciples of the new religion. Violent, implacable, and irresistible at the moment of conquest, the Arabs were not unjust or hard masters in countries which submitted to their conditions. Every endeavour was, of course, made to proselytise, but Christians were allowed to preserve their religion on payment of a tax, and even Popes were in the habit of entering into friendly relations with the invaders. The Church of St. Cyprian and St. Augustine, with its 500 Sees, was indeed expunged, but five centuries after the passage of the Mohammedan army from Egypt to the Atlantic a remnant of it still existed. It was not till the 12th century that the religion and language of Rome became utterly extinguished.

The Arabs introduced a high state of civilisation into the countries where they settled; their architecture is the wonder and admiration of the world at the present day; their irrigational works in Spain have never been improved upon; they fostered literature and the arts of peace, and introduced a system of agriculture far superior to what existed before their arrival.

Commerce, discouraged by the Romans, was highly honoured by the Arabs, and during their rule the Mediterranean recovered the trade which it possessed in the time of the Phœnicians and Carthaginians; it penetrated into the Indian Archipelago and China; it travelled westward to the Niger, and to the east as far as Madagascar, and the great trade route of the Mediterranean was once more developed.

The power and prosperity of the Arabs culminated in the ninth century, when Sicily fell to their arms; it was not, however, very long before their empire began to be undermined by dissensions; the temporal and spiritual authority of the Ommiade Khalifs, which extended from Sind to Spain, and from the Oxus to Yemen, was overthrown by the Abbasides in the year 132 of the Hedjira, A.D. 750. Seven years later Spain detached itself from the Abbaside empire; a new Caliphate was established at Cordova, and hereditary monarchies began to spring up in other Mohammedan countries.

The Carlovingian empire gave an impulse to the maritime power of the South of Europe, and in the Adriatic the fleets of Venice and Ragusa monopolised the traffic of the Levant. The merchants of the latter noble little republic penetrated even to our own shores, and Shakespeare has made the Argosy or Ragusie a household word in our language.

During the eleventh century the Christian Powers were no longer content to resist the Mohammedans; they began to turn their arms against them. If the latter ravaged some of the fairest parts of Europe, the Christians began to take brilliant revenge.

The Mohammedans were driven out of Corsica, Sardinia, Sicily, and the Balearic Islands, but it was not till 1492 that they had finally to abandon Europe, after the conquest of Granada by Ferdinand and Isabella.

About the middle of the eleventh century an event took place which profoundly modified the condition of the Mohammedan world. The Caliph Mostansir let loose a horde of nomad Arabs, who, starting from Egypt, spread over the whole of North Africa, carrying destruction and blood wherever they passed, thus laying the foundation for the subsequent state of anarchy which rendered possible the interference of the Turks.

English commercial intercourse with the Mediterranean was not unknown even from the time of the Crusades, but it does not appear to have been carried on by means of our own vessels till the beginning of the sixteenth century. In 1522 it was so great that Henry VIII. appointed a Cretan merchant, Censio de Balthazari, to be 'Master, governor, protector, and consul of all and singular the merchants and others his lieges and subjects within the port, island, and country of Crete or Candia.' This is the very first English consul known to history, but the first of English birth was my own predecessor in office, Master John Tipton, who, after having acted at Algiers during several years in an unofficial character, probably elected by the merchants themselves to protect their interests, was duly appointed consul by Sir William Harebone, ambassador at Constantinople in 1585, and received just such an exequatur from the Porte as has been issued to every consul since by the government of the country in which he resides.

Piracy has always been the scourge of the Mediterranean, but we are too apt to associate its horrors entirely with the Moors and Turks. The evil had existed from the earliest ages; even before the Roman conquest of Dalmatia the Illyrians were the general enemies of the Adriatic; Africa under the Vandal reign was a nest of the fiercest pirates; the Venetian chronicles are full of complaints of the ravages of the Corsairs of Ancona, and there is no other name but piracy for such acts of the Genoese as the unprovoked pillage of Tripoli by Andrea Doria in 1535. To form a just idea of the Corsairs of the past it is well to remember that commerce and piracy were often synonymous terms, even among the English, up to the reign of Elizabeth. Listen to the description given by the pious Cavendish of his commercial circumnavigation of the globe: 'It hath pleased Almighty God to suffer me to circumpass the whole globe of the world. . . . I navigated along the coast of Chili, Peru, and New Spain, where I made great spoils. All the villages and towns that ever I landed at I burned and spoiled, and had I not been discovered upon the coast I had taken a great quantity of treasure;' and so he concludes, 'The Lord be praised for all his mercies!'

Sir William Monson, when called upon by James I. to propose a scheme for an attack on Algiers, recommended that all the maritime powers of Europe should contribute towards the expense, and participate in the gains by the sale of Moors and Turks as slaves.

After the discovery of America and the expulsion of the Moors from Spain, piracy developed to an extraordinary extent. The audacity of the Barbary corsairs seems incredible at the present day; they landed on the shores and islands of the Mediterranean, and even extended their ravages to Great Britain, carrying off all the inhabitants whom they could seize into the most wretched slavery. The most formidable of these piratical states was Algiers, a military oligarchy, consisting of a body of janissaries, recruited by adventurers from the Levant, the outcasts of the Mohammedan world, criminals and renegades from every nation in Europe. They elected their own ruler or Dey, who exercised despotic sway, tempered by frequent assassination; they oppressed without mercy the natives of the country, accumulated vast riches, had immense numbers of Christian slaves, and kept all Europe in a state bordering on subjection by the terror which they inspired. Nothing is sadder or more inexplicable than the shameful manner in which this state of things was accepted by civilised nations. Many futile attempts were made during successive centuries to humble their arrogance, but it only increased by every manifestation of the powerlessness of Europe to restrain it. It was reserved for our own countryman, Lord Exmouth, by his brilliant victory in 1816, for ever to put an end to piracy and Christian slavery in the Mediterranean. His work, however, was left incomplete, for though he destroyed the navy of the Algerines, and so rendered them powerless for evil on the seas, they were far from being humbled; they continued to slight their treaties and to subject even the agents of powerful nations to contumely and injustice. The French took the only means possible to destroy this nest of ruffians, by the almost unresisted occupation of Algiers and the deportation of its Turkish aristocracy.

They found the whole country in the possession of a hostile people, some of whom had never been subdued since the fall of the Roman empire, and the world owes France no small debt of gratitude for having transformed what was a savage and almost uncultivated country into one of the richest as well as the most beautiful in the basin of the Mediterranean.

What has been accomplished in Algeria is being effected in Tunisia. The treaty of the Kasr-es-Saeed, which established a French Protectorate there, and the military occupation of the Regency, were about as high-handed and unjustifiable acts as are recorded in history; but there can be no possible doubt regarding the important work of civilisation and improvement that has resulted from them. European courts of justice have been established all over the country; the exports and imports have increased from 23 to 51 millions of francs, the revenue from 6 to 19 millions, without the imposition of a single new tax, and nearly half a million per annum is being spent on education.

Sooner or later the same thing must happen in the rest of North Africa, though at present international jealousies retard this desirable consummation. It seems hard to condemn such fair countries to continued barbarism, in the interest of tyrants who misgovern and oppress their people. The day cannot be far off when the whole southern shores of the Mediterranean will enjoy the same prosperity and civilisation as the northern coast, and when the deserts, which are the result of misgovernment and neglect, will assume the fertility arising from security and industry, and will again blossom as the rose.

It cannot be said that any part of the Mediterranean basin is still unknown, if we except the empire of Morocco. But even that country has been traversed in almost every direction during the past twenty years, and its geography and natural history have been illustrated by men of the greatest eminence; such as Gerhard Rohlfs, Monsieur Tissot, Sir Joseph Hooker, the Vicomte de Foucauld, Joseph Thomson, and numerous other travellers. The least known portion, at least on the Mediterranean coast, is the Riff country, the inhospitality of whose inhabitants has given the word 'ruffian' to the English language. Even that has been penetrated by De Foucauld disguised as a Jew, and the record of his exploration is one of the most brilliant contributions to the geography of the country which has hitherto been made.

Although, therefore, but little remains to be done in the way of actual exploration, there are many by-ways of travel comparatively little known to that class of the community with which I have so much sympathy, the ordinary British tourist. These flock every year in hundreds to Algeria and Tunis, but few of them visit the splendid Roman remains in the interior of those countries. The Cyrenaica is not so easily accessible, and I doubt whether any Englishmen have travelled in it since the exploration of Smith and Porcher in 1861.

Cyrene almost rivalled Carthage in commercial importance. The Hellenic ruins still existing bear witness to the splendour of its five great cities. It was the birthplace of many distinguished people, and amongst its hills and fountains were located some of the most interesting scenes in mythology, such as the Gardens of the Hesperides and the 'Silent, dull, forgetful waters of Lethe.'

This peninsula is only separated by a narrow strait from Greece, whence it was originally colonised. There, and indeed all over the eastern basin of the Mediterranean, are many little-trodden routes; but the subject is too extensive; I am reluctantly compelled to restrict my remarks to the western half.

The south of Italy is more frequently traversed and less travelled in than any part of that country. Of the thousands who yearly embark or disembark at Brindisi, few ever visit the Land of Manfred. Otranto is only known to them from the fanciful descriptions in Horace Walpole's romance. The general public in this country is quite ignorant of what is going on at Taranto, and of the great arsenal and dockyard which Italy is constructing in the Mare Piccolo, an inland sea containing more than 1,000 acres of anchorage for the largest ironclads afloat, yet with an entrance so narrow that it is spanned by a revolving bridge. Even the Adriatic, though traversed daily by steamers of the Austrian Lloyd's Company, is not a highway of travel; yet where is it possible to find so many places of interest within the short space of a week's voyage, between Corfu and Trieste, as along the Dalmatian and Istrian shores, and among the islands that fringe the former, where it is difficult to realise that one is at sea at all, and not on some great inland lake?

There is the Bocche di Cattaro, a vast rent made by the Adriatic among the mountains, where the sea flows round their spurs in a series of canals, bays, and lakes of surpassing beauty. The city of Cattaro itself, the gateway of Montenegro, with its picturesque Venetian fortress, nestling at the foot of the black mountain, Ragusa, the Roman successor of the Hellenic Epidaurus, Queen of the Southern Adriatic, battling with the waves on her rock-bound peninsula, the one spot in all that sea which never submitted either to Venice or the Turk, and for centuries resisting the barbarians on every side, absolutely unique as a mediæval fortified town, and worthy to have given her name to the argosies she sent forth; Spalato, the grandest of Roman monuments; Lissa, colonised by Dionysius of Syracuse, and memorable to us as having been a British naval station from 1812 to 1814, while the French held Dalmatia; Zara, the capital, famous for its siege by the Crusaders, interesting from an ecclesiological point of view, and venerated as the last resting-place of St. Simeon, the prophet of the *Nunc dimittis*; Parenza, with its great

Basilica; Pola, with its noble harbour, whence Belisarius sailed forth, now the chief naval port of the Austrian empire, with its Roman amphitheatre and graceful triumphal arches; besides many other places of almost equal interest. Still further west are Corsica, Sardinia, and the Balearic Islands, all easily accessible from the coasts of France, Italy, and Spain. Their ports are constantly visited by mail steamers and private yachts, yet they are but little explored in the interior.

I am tempted to linger a little over one of the places I have just mentioned, and to devote more time to a physical and historical description of Corsica than I can spare for the Mediterranean generally. It is replete with all that makes travel delightful—unequalled scenery, a brilliant climate, historical associations, and the study of a race of men who still retain their national peculiarities. The facilities for travelling are as great as can be fairly expected; roads such as none but the French seem able to make, winding along steep coasts and over high mountains, plunging into the depths of shady valleys and amongst dark forests in search of what is so dear to a French engineer's heart, a uniform gradient, and metalled with granite so hard that in the driest weather they are free from dust. I may add that I never failed to find sufficiently good accommodation and a kindly reception in the smallest and most remote villages.

Corsica has been compared in shape to a closed hand with the index finger extended, the latter being the promontory called Cap Corse. The island is traversed in its whole length by a chain of high mountains, the general direction of which is north and south, dividing it into two parts of nearly equal extent. Placed, as it is, in the centre of the Western Mediterranean, between the Alps and the Atlas, and with so great inequalities of surface, it presents an epitome of the whole region from the warm sea-level to the Alpine character of the interior, where the mountains rise to a height of nearly 9,000 feet, and are clothed in snow during the greater part of the year.

All the western coast, and more than two-thirds of the whole island, are of granitic formation. The central range throws out spurs towards the sea, forming on the western side numerous bays of considerable size and depth. Nothing can exceed the grandeur of the scenery on the coast which culminates in the celebrated Calanches de Piana, a succession of stupendous granite rocks worn and hollowed out in the most fantastic manner, fearful in their forms but soft and lovely in their colouring. There are many similar rocks throughout the island, such as the Calanches d'Evisa, the Fourches d'Asinao, and the Gorge of Inzeca, where a river flows between great cliffs and amongst boulders of green serpentine, a sight never to be forgotten.

The eastern side of the island consists of primary rocks, more or less easily disintegrated, the detritus being washed down by rains, so as to form the low plains bordering that coast. As the rivers force their way through them with difficulty, marshes and lagoons are created. These are hotbeds of malarious fever in summer, dangerous even for the natives, who migrate to the hills at that season.

The forests, the great glory of the island, consist chiefly of oak, beech, birch, and the *Pinus laricio*, indigenous to Corsica, and the monarch of European conifers, which rises as straight as an arrow, sometimes to a height of 120 or 150 feet.

The Castagniccia, or country of the chestnut, is an extensive and very beautiful district, especially when the trees are in full leaf. The fruit is more useful to the people who inhabit the district than even the date to the Arab. He has to cultivate his palm trees laboriously, irrigate them in summer, and pick the fruit with the greatest care. The chestnut demands no such attention; it grows spontaneously, requires no cultivation, and the fruit falls of itself when sufficiently ripe. It is the staple food of the people, who eat it in every form, even giving it to their cattle instead of grain, while the sale of the surplus furnishes them with the other necessaries of life.

After the forests the most pleasing feature in the island, and covering more than half its surface, is the macchie, or brushwood, before mentioned, spreading its delicious perfume through the air and lighting up the landscape with a blaze of colour. There is also a constant succession of wild flowers, liliaceous plants, orchids, cyclamen, and many others. In one pine wood I saw the ground carpeted with violets and primroses, while ferns, from the common bracken to the noble *Osmunda regalis*, are found everywhere.

The principal towns are Ajaccio on the south-west, a well-known winter station, the capital of the island, full of memories and memorials of Napoleon; Bastia to the north-east, the commercial capital; Calvi to the north-west, a picturesque stronghold rising high above the sea, and dominating the surrounding country. The last is one of the few places that were always faithful to the Genoese cause, and it still bears over the entrance gate the inscription, *Civitas Calvi semper fidelis.* It made a desperate resistance to the English in 1794 under Hood and Nelson, who reduced it almost to a heap of ruins before it surrendered. Nelson lost his eye in the engagement. A local antiquary has tried to prove that Columbus was born here, of Genoese parents, though he left at an early age for Genoa.

Corte, in the interior of the island, the ancient feudal capital, was the chief seat of Paoli's government, as well as the headquarters of the short-lived English administration under Sir Gilbert Elliot. It is situated at the confluence of two rivers, the Restonica and the Tavignano, which descend to the plains through a series of magnificent gorges. High above the town, perched on the summit of a rock, is the picturesque citadel built in the beginning of the fifteenth century.

In the extreme south is Bonifacio, another ancient fortress, not only strange and beautiful in itself, but commanding fine views from its ramparts of Sardinia and the numerous islands on both sides of the Straits.

Cargese, 28 miles north of Ajaccio, is exceptionally interesting. In 1676 an emigration of about 1,000 Greeks from Maina, in the Morea, wearied with Turkish oppression, took place to Genoa, whence they were sent to Corsica. A second emigration of 400 started to join them in the following year, but they were overtaken by the Turkish fleet and massacred. The prosperity of the small colony was not of long duration, because, when the insurrection in Corsica against the Genoese broke out, the Greeks, out of gratitude to their protectors, refused to join in it. In consequence their villages were destroyed, their lands confiscated, and their flocks driven away. They fled for refuge to Ajaccio, and there remained till the advent of the French. It was one of the first acts of Comte Marbeuf, on assuming the government of the island, to reinstate them in a new domain, and he it was who built the present town of Cargese. The inhabitants, though in full communion with the Church of Rome, still retain their Greek Liturgy, and to some extent their language, and live on the most cordial terms with their Latin neighbours.

The vendetta has always been one of the characteristic customs of Corsica, although prevailing more in some parts of the island than in others. Such feuds have been pursued with inveterate pertinacity, frequently involving whole families from one generation to another. The custom originated in times when Genoese justice was venal and corrupt, and men had to take the honour of their families into their own keeping. After having accomplished their vendetta, the 'bandits,' as they are called, are accustomed to take refuge in the macchie, but they are never to be confounded with robbers, and there is no instance of strangers being molested by them.

Corsica has an important ancient history, but time will not permit me to enter into this subject in any detail; one episode, however, is especially interesting. Seneca passed eight years here in exile: a tower is pointed out on the west coast of Cap Corse which is said to have served as his prison. Even the glorious views of sea and land which it commands could not compensate him for compulsory banishment from the fertile plains of Italy. He may therefore be pardoned for his petulant injustice to the physical geography of the island when he penned his celebrated complaint, thus rendered by Boswell:—

> Corsica, whom rocks terrific bound,
> Where nature spreads her wildest deserts round,
> In vain revolving seasons cheer thy soil,
> Nor rip'ning fruits nor waving harvests smile;
> Nor blooms the olive mid the winter drear;
> The votive olive to Minerva dear.

See spring returning spreads her milder reign !
Yet shoots no herb, no verdure clothes the plain,
No cooling springs to quench the traveller's thirst
From thy parched hills in grateful murmurs burst ;
Nor, hapless Isle ! thy barren shores around,
Is wholesome food, fair Ceres' bounty, found.
Nor even the last sad gift the wretched claim,
The pile funereal and the sacred flame ;
Naught here, alas ! surrounding seas enclose,
Naught but an exile and an exile's woes.

Nor is this the place even to summarise the modern history of the island, though nothing can be more interesting than the story of the Pisan domination, the long and tyrannical rule of the Genoese, the struggle of the islanders during four centuries to regain their independence, the mock kingdom of Theodore, the wise rule of Pasquale Paoli, the unfortunate English occupation, and the subsequent conquest of the island by France.

I have endeavoured to sketch, necessarily in a very imperfect manner, the physical character and history of the Mediterranean; to show how the commerce of the world originated in a small maritime state at its eastern extremity: how it gradually advanced westward till it burst through the Straits of Gibraltar, and extended over seas and continents until then undreamt of, an event which deprived the Mediterranean of that commercial prosperity and greatness which for centuries had been limited to its narrow basin.

Once more this historic sea has become the highway of nations; the persistent energy and genius of two men have revolutionised navigation, opened out new and boundless fields for commerce, and it is hardly too much to say that if the Mediterranean is to be restored to its old position of importance, if the struggle for Africa is to result in its regeneration, as happened in the new world, if the dark places still remaining in the further East are to be civilised, it will be in a great measure due to Waghorn and Ferdinand de Lesseps, who developed the overland route and created the Suez Canal.

But the Mediterranean can only hope to retain its regenerated position in time of peace. Nothing is more certainly shown by past history than that war and conquest have changed the route of commerce in spite of favoured geographical positions. Babylon was conquered by Assyrians, Persians, Macedonians, and Romans, and though for a time her position on the Euphrates caused her to rise like a Phœnix from her ashes, successive conquests, combined with the luxury and effeminacy of her rulers, caused her to perish. Tyre, conquered by Nebuchadnezzar and Alexander, fell as completely as Babylon had done, and her trade passed to Alexandria. Ruined sites of commercial cities rarely again become emporia of commerce; Alexandria is an exception dependent on very exceptional circumstances.

The old route to the East was principally used by sailing vessels, and was abandoned for the shorter and more economical one by the Suez Canal, which now enables a round voyage to be made in 60 days, which formerly required from six to eight months. This, however, can only remain open in time of peace. It is quite possible that in the event of war the old route by the Cape may be again used, to the detriment of traffic by the Mediterranean. Modern invention has greatly economised the use of coal, and steamers, by the use of duplex and triplex engines, can run with a comparatively small consumption of fuel, thus leaving a larger space for cargo. England, the great carrying power of the world, may find it more advantageous to trust to her own strength and the security of the open seas than to run the gauntlet of the numerous strategical positions in the Mediterranean, such as Port Mahon, Bizerta, and Taranto, each of which is capable of affording impregnable shelter to a hostile fleet, and though the ultimate key to the Indian Ocean is in our own hands, our passage to it may be beset with a thousand dangers. There is no act of my career on which I look back with so much satisfaction as on the share I had in the occupation of Perim, one of the most important links in that chain of coaling stations which extends through the Mediterranean to the further East, and which is so necessary for the maintenance of our naval supremacy. It is a mere islet, it is true, a barren rock, but one surrounding a noble harbour, and so eminently in its right place that we cannot contemplate with equanimity the possibility of it being in any other hands than our own.

It is by no means certain whether exaggerated armaments are best suited for preserving peace or hastening a destructive war; the golden age of disarmament and international arbitration may not be near at hand, but it is even now talked of as a possibility.

Should the poet's prophecy or the patriot's dream be realised, and a universal peace indeed bless the world, then this sea of so many victories may long remain the harvest field of a commerce nobler than conquest.

The following Papers were read:—

1. *The Vertical Relief of the Globe. By* H. R. MILL, *D.Sc., F.R.S.E.*

This was a brief account of investigations already described in the 'Scottish Geographical Magazine' for 1890.

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2. *Geographical Teaching in Russia. By* H. R. MILL, *D.Sc., F.R.S.E.*

The author dealt mainly with Russian text-books of geography, which he exhibited, showing how by means of maps of different scales the pupil is led out from his immediate neighbourhood to the geography of his district, his province, and so on, to still greater areas. Dr. Mill also pointed out the defects of the Russian system.[1]

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3. *A Railway through Southern Persia.*[2]
By Major-General Sir F. J. GOLDSMID, *C.B., K.C.S.I., F.R.G.S.*

This paper is intended as a supplement to one read in June 1878, at the Royal United Service Institution, on 'Communications with British India under Possible Contingencies.' The main object on that occasion was to advocate the construction of a line of railway connecting the western shores of the Mediterranean with the western coast of India by a direct, convenient, and politically expedient route—a great part of which, on the eastern side, though *terra incognita* to the many, had chanced to come under the personal examination of the writer and one or two brother-officers. After delivery of the address (repeated by request at the Royal Engineers' Institute, Chatham), a leading article and some prolonged correspondence in the *Times*, and more than one leading article in the *Daily Telegraph*, directed public attention to the subject, interest in which was enhanced by the subsequent occupation of Cyprus—practically the step recommended as an introduction to railway operations on the coast opposite Famagusta.

One part of the programme originally sketched out, however, was wanting in essential details. It was not laid down with any precision what should be the actual course taken by the through line to India when branching off from the Lower Euphrates. Surveys and reports by recent travellers have now rendered it easy to supply this link of rail, one which may be appropriately called the Baghdad-Bandar-Abbas section, or, more minutely, the Baghdad-Shiráz and Shiráz-Bandar-Abbas sections. As to the route from Bandar-Abbas to Karáchi on the east, and from Tripoli to Baghdad on the west, any doubts or difficulties that present themselves are already ripe for discussion, and their solution cannot be treated as dependent upon further travel and research.

It is proposed to carry the line from Baghdad through Persian Arabistan, either by way of Dizful and Shustar, continuing along the recognised track from the latter place to Bebehan; or by an alternative route down the left bank of the Tigris, and *viâ* Haweizah to Ahwaz, whence Major Wells, R.E., has furnished full details of

[1] A full abstract in *Proc. R.G.S.* vol. xii. p. 669.
[2] Printed in full in the *Scottish Geographical Magazine*, vol. vii.

the route from his own experiences. The same officer has made, moreover, very valuable suggestions on the mode of reaching Shiráz from Bebehan. Comparing the obstacles presented in this direction with those apparent in the more northern tract of country, he writes:—

'I think the railway engineer would prefer to take the line from Shustar *viâ* Bebehan to the Ardakhan Valley. He would find no stupendous obstacles this way, and would have wormed himself to the roof of Central Persia without crossing one of the ridges that would guard it; he would tap, too, its most fertile plains and include Shiráz. The 7,200 feet *kotul* that lies between Ardakhan and Shiráz has no difficulties or gradients that a "Fairlie's" engine, such as is used between Poti and Tiflis, would not surmount. Or I should recommend the trial of the valley of the Shâpur river from Bushire to Nodun, where a tunnel would lead through to the river Shur or Fahliyun, which runs from Ardakhan.'

On the country east and south-east of Shiráz the reports of travellers are noted, and stress is laid upon the views of Mr. Preece of the Persian Telegraph, expressed in the following extract from his report of a journey through Daráb and Forg:—

'Should at any time the question of a railway to the Persian Gulf take tangible form, a careful survey of this route, I am convinced, will repay the projectors. As against the Shiráz-Bushire route, there can be no doubt of its greater adaptability . . . the engineering difficulties are nearly *nil*. . . . a railway along this route would tap a large grain-growing country, and would be easy of access to the inhabitants of Yezd and Kirmán.'

An alternative route is also mentioned, running south of Mr. Preece's, through Lar; it is reported on by a late French traveller, M. Rochechouart, formerly Chargé d'Affaires at the Shah's Court.

A brief notice is given of Shustar, Shiráz, and Bandar-Abbas, and the lines of traffic leading to these places. The writer brings his paper to a conclusion by expressing his great faith in the drastic remedy of the iron rail and locomotive, to awaken a slumbering but active-minded people, for whom it would be a novelty of high price and usefulness. He does not, however, disguise the fact that the scheme of railway which he describes has not had its origin in the mere wish to benefit a particular nation, but rather in the intention of putting in a 900-mile link in the inevitable great line which will some day connect England with her Indian Empire, and which should be as readily available to passengers and goods as any of the more popular and successful lines at home.

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4. *New Trade Routes into Persia.* *By* H. F. B. LYNCH.

This paper had as its object an attempt to review the commercial geography of Southern Persia from the standpoint of the writer's experience during recent travels. A twofold consideration at once presented itself: firstly, what was the physical configuration of the country between the Persian Gulf and the Persian plateau, and, secondly, how could we apply the results of such an inquiry to the benefit of commerce and of civilisation. Here an important element was introduced; for, given that geography had long ago decided that the present main trade route was about the worst possible, and further, that she had, within recent years, added much positive information regarding better roads, there still remained the important questions, Might commerce enter by them, and, if allowed to enter, would she be starved or fostered? This was the political element, and he would venture to offer a few remarks regarding it. The chief obstacles to the progress of commerce in Persia lay not only in the indifference of the Persian Government, but also in the apathy of the English people towards Persia and its politics. The English people had the largest interest in the foreign commerce of that Power which was no distant neighbour of theirs in India; and, further, the value to them of its political stability was such as to merit not their apathy but their zeal. Stretching from the eastern borders of Turkey to the frontiers of Afghanistan and from the Transcaspian provinces of Russia to the Indian Ocean, Persia covered an area of 610,000 square miles—a territory five times as large as that comprised within the United Kingdom. Of this the greater portion was mountain or springless desert: enough remained of arable, of habitable, and of salubrious districts to equal or exceed the area of our islands. The political importance to us of the development of Persia as an integral state was this: it would be onerous to hold it ourselves, it would be dangerous to let others hold it, it would be advantageous if it could progress—but progress it must—under its present rulers. When the Karun River—a great navigable waterway, and the only navigable river of Persia—was thrown open to commerce under certain almost prohibitive conditions by H.M. the Shah in 1888, the prospect of improved intercourse with Persia was received with some interest by the English press. If certain restrictions could be removed, and if certain facilities were offered, it seemed likely that the new trade routes, the advantages of which our geographers had taken great pains to demonstrate, would descend from the province of theory to that of reality. This hope, in spite of the arduous labours of those who were well acquainted with the methods and habits of the East, had only been partially realised. While H.M. the Shah was being fêted by the merchants of London, the writer himself, as a traveller, was a witness of the scanty help—to say the least—which the Persian Government were extending to London merchants engaged in laborious work on the Karun. Individuals could only point out what measures it was necessary to take to facilitate commerce; our Government alone had the power to see that they were taken. A mere declaration that a river might be navigated was not tantamount to opening it to commerce. In what manner its proper navigation would affect commercial intercourse it was now his object to describe.

After some general remarks regarding the physical geography of Persia as bearing on the subject under consideration, the speaker proceeded to point out that the largest cities and the central points of attraction to commerce by the Persian Gulf were situated on the Persian plateau. Of these Ispahan contained some 80,000 and Teheran some 200,000 inhabitants. The volume of Persian trade flowed from and to the Persian Gulf by means of mule or camel transport; from the gulf there was cheap water carriage to India and to Europe. A portion passed by the Black Sea route *viâ* Trebizond, while the rich province of Khorassan and the shores of the Caspian were enclosed within the widening zone of Russian commercial supremacy. Bushire stood at the entrance of the main avenue of the Gulf trade; thence a most difficult track led over high and precipitous passes to Shiraz; from Shiraz the way was easier towards Ispahan and Teheran. The distances along this, the principal road, at present, into Persia by the Gulf, were:—Shiraz, 200 miles; Ispahan, 520 miles; Teheran, 800 miles; and the elevations—between Bushire and Shiraz a pass of 7,250 feet; between Shiraz and Ispahan, one of over 8,000 feet; between Ispahan and Teheran, the Kohrud Pass of 8,750 feet. The difficulties along this road were so great that bulky goods destined for Persia were taken by river to Bagdad, and thence, after passing the barriers of a Turkish custom-house, reached the Persian plateau by the easier route *viâ* Kerrind. A glance at the map would show the advantages which Shushter, at the head of the navigable portion of the Karun River, possessed over Bushire. There you had a port distant some 130 miles by land from the Persian port of Mohammerah, to which ocean steamers had access. Shushter commanded a series of routes to the more populous districts and cities of Persia. The chief among these were:—1. From Shuster *viâ* Khoremabad, Burujird, and Sultanabad to Teheran, a distance of 480 miles, as against 800 between Teheran and Bushire. The elevations along this road were:—For a distance of about 110 miles its profile rose from under 6,000 feet to passes over 7,000 feet high, the highest being that of Kushkedar, between Sultanabad and Burujird, 7,490 feet high. A group of European capitalists were engaged in constructing a cart road along this section. 2. From Shushter *viâ* Malamir to Ispahan, a distance of 250 miles by the road which he had described in the current number of the Royal Geographical Society's Proceedings. The higher altitudes along this road extended for a distance of about 73 miles, and the highest pass along it was about 8,650 feet high. By these two roads the distance between Teheran and a port was reduced from 800 miles *viâ* Bushire to 480 miles *viâ* Shushter, while Ispahan held the benefit of 250 as against 520 miles. The first of the two routes from Shushter traversed a country which had been subject to the depredations of the Lur tribes; but the opening of the Karun River and the revenues derived from increased commerce would make it worth while for the Persian Government to ensure its security. As to the second it lay through the country of the friendly Bakhtiari, who were well within the authority of the Persian Government.

It was now nearly two years since the Karun River had been declared open to navigation as far as Ahwaz, at which point there was a natural dam across the stream. A continuous steam service had, after much negotiation, been organised both above and below Ahwaz. Why was commerce still loth to enter and avail itself of the new trade routes? This was an important question which those interested in commercial geography would not hesitate to ask. The commerce of Great Britain and India with Persia had been estimated recently by a careful writer at a value of 2,500,000*l.* a year. That figure alone made it seem worth while to attempt an answer. The reasons might be briefly stated thus:—1. The collection of customs was still in a state of disorder; a settlement had been arrived at nearly a year ago between the British and the Persian Governments by which the customs were to be collected at Shushter, the port of terminus, but this important measure still remained unfulfilled. 2. A postal service on the Karun required to be organised; this was a matter for our own Government, and its importance had been pointed out by Colonel Bell and Sir R. Murdoch Smith. These were the leading obstacles to commerce as far as Shushter; once it had penetrated thither it would soon pass further. The development of the short track to Ispahan was well within the power of the Persian Government. The advantages which would accrue to Persia by the use of the new trade routes would be enormous. The benefits to ourselves and to European commerce would not be insignificant. In the past our interest in Persia had been spasmodic; sometimes we had thought no expenditure too extravagant, at others we had wrapped ourselves in a cold indifference to her fate. Would the new era repeat the uneven history of the old?

FRIDAY, SEPTEMBER 5.

The following Papers were read:—

1. *Notes on the Country lying between Lakes Nyassa, Rukwa, and Tanganyika.*[1] *By* Dr. Kerr Cross.

This paper describes the Ukonda plains at the north and west of Nyassa, the people, their villages, banana groves, gardens, customs, &c. It also deals with the hill-countries north of these, describes their valleys and rivers.

Then, leaving these, it describes the Stevenson road travelling from Karonga to the extensive plateau country between the two lakes. The stockaded villages of the people are described. The rivers are referred to—those running south into the Zambezi and the Indian Ocean, those south and west into the Chambezi being the eastern source of the Congo. The watershed of Lake Nyassa and Lake Rukwa are described, with the country around. This little-known and brackish lake, Leopold or Rukwa, is described, with the country at its south end. Certain of the rivers flowing into it are described.

The commercial capabilities of Nyassaland generally are referred to; its rainfall, its temperature, the richness of its soil, and its capacity for raising European products. The question of native labour and European colonisation are pretty fully gone into.

[1] Printed in *Proc. R.G.S.* vol. xiii.

2. *Journeys in Ashanti and Neighbouring Regions.* *By* R. AUSTIN FREEMAN, *M.R.C.S.*

The paper describes a journey through a tract of country in and to the north of Upper Guinea, comprising the territories of FÁNTI, ASSÍN, ÁDÁNSI, ASHÁNTI, JÁMAN, and GRÚINSI. This tract extends from 5° N. to 10° N., and from 0° to 4° W. The first four countries are inhabited by various branches of the great ŌTSHWÍ family, and the remainder by certain pagan aboriginal tribes, and by numbers of WONGÁRA or Mandingo immigrants. Journeying from Cape Coast, through Ashánti to Bontúku, the capital of Jaman, the author crossed three zones of country: (1) open country covered with low bush about 30 miles broad; (2) dense forest about 180 miles broad; (3) open park-like country which, alternating with grassy plains, seems to occupy the greater part of Central and Eastern Africa. On arrival at KUMASSI, the capital of Ashánti, the author was received by the king and principal chiefs with great ceremony, the court of Kumassi retaining much of its former splendour. The town of Kumassi is much dilapidated, but presents many relics of great interest. Jáman is a kingdom situated to the N.W. of Ashánti, about 9,300 square miles in extent; its capital, BONTÚKU, is a large town closely resembling in appearance the towns of the Tawarek and upper Niger. It is inhabited almost exclusively by Mohammedans, and forms an important slave depôt, as do also the Grúinsi towns of WÀ and BÓRI. The commercial resources of the tract of country here described are considerable; over the whole of it gold is fairly plentiful, and the forest abounds in rubber plants both in the form of trees and vines. Hard woods are very plentiful, and are of great value in Europe, notably the ODÚM and PAPPÁO, both of which trees reach a height of nearly 200 feet. The Kola nut also, which grows abundantly in the forest, has a great and increasing commercial value. The country is intersected by several considerable rivers which might be easily rendered navigable, and thus form great highways of trade. There are, moreover, no special obstacles to the construction of railways, and the district may thus be expected to form one of the great commercial centres of the future.

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3. *Zambezia.*[1] *By* E. A. MAUND.

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4. *The Commercial Geography of Africa.* *By* J. SCOTT KELTIE.

The author reviewed the physical characters of Africa, so far as known, and pointed out the probable bearings of them in the commercial development of the Continent. He showed that, while all the natural vegetable and animal matter and nearly the whole of the rainfall and water supply are concentrated in tropical Africa, the value of the commerce of that region is insignificant compared with that of the Mediterranean region and South Africa. In Central Africa nature has been left to herself; in North and South Africa man has interfered with profitable results.

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5. *The Political Partition of Africa.* *By* A. SILVA WHITE, *F.R.S.E.*

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6. *The Kalahari.* *By* E. WILKINSON.

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[1] See *Proc. R.G.S.* vol. xiii. p. 1.

MONDAY, SEPTEMBER 8.

The following Papers and Report were read:—

1. *Joint Meeting with Section F to consider the subject of the Lands of the Globe still available for European Settlement. Introduced in a Paper by* E. G. RAVENSTEIN, *F.R.G.S.*[1]

2. *On Exploration in North-Eastern Cilicia.*[2] *By* J. THEODORE BENT.

After showing how geography, history, and anthropology are interwoven in this district, and the study of one is necessary to the understanding of the other, the author gave an account of the Armenian fortress of Sis, and the reason for its importance during the Roupenian line of Armenian kings.

The country between Sis and Anazarba was then described, and an account given of the fortress-town of Anazarba and the rivers Jeihan, Sombaz, and Savroon.

Experiences amongst the nomad tribes, and their customs and mode of living were then given, including the Afshars, the Bosdans, and the Circassians, who frequent this portion of the Cilician plains during the winter months.

The country between Anazarba and Kars Bazaar was described, and this place identified with the ancient Flaviopolis.

Exploration of ruins on a spot near the Pyramus, called Bodroum, was then described, and its identification from epigraphy with the ancient Hieropolis-Castabala.

Inscriptions which show that Artemis Perasia was worshipped here, as Strabo tells us, were referred to to show that this is the Castabala which has hitherto been placed in Cappadocia, and is also the spot which Alexander the Great visited before the battle of Issos.

Notes on Osmanieh and the pass behind it leading into Syria.

3. *Report of the Committee for the Exploration of Cilicia.*—See Reports, p. 535.

4. *The Physical Geographical Features of Brazil, in relation to their Influence upon the Development, or otherwise, of the Industrial and Commercial Interests of the Country.*[3] *By* JAMES W. WELLS, *M.Inst.C.E., F.R.G.S.*

The purpose of the paper is to point out the contrast between the configuration of the land of Argentina and of Brazil: how in the former it is so extremely favourable to the rapid and inexpensive extension of railways; whereas in the latter country it has long been an obstacle to similar progress. Now that such obstacles have largely been overcome, there is every prospect of a speedy construction of a vast system of rail and fluvial communication over the vast area of Brazil—a result which will be, and, as a matter of fact, actually is, the means of attraction of a considerable number of desirable immigrants. And railway construction, and a free and abundant immigration, inevitably lead to the development of all sorts and conditions of industries, and prosperous commerce.

5. *From Paraguay to the Pacific.* *By* M. A. THOUAR.

M. Thouar made four expeditions in South America. In his first, made under the auspices of the Bolivian Government in 1883, following the disappearance of

[1] Full report in *Proc. R.G.S.* vol. xiii. p. 27.
[2] See *Proc. R.G.S.* vol. xii. p. 445.
[3] See *Scottish Geographical Magazine*, vol. vi.

the Crevaux Mission, he explored the unknown regions through which flows the river Pilcomayo. The second in 1885, under the auspices of the Argentine Government, was devoted to an overland exploration of the delta of the Pilcomayo lying in the Argentine territory. The third, in 1886, was made in a northerly direction from Rosaria to Salta, reascending the Humanuaca and the Cordilleras. The fourth, under the auspices of the Bolivian Government, was made for the purpose of discovering a navigable route eastwards for the commerce and productions of Bolivia.

At the head of an escort of twenty men, afterwards increased to seventy, M. Thouar left Chuquisaca in November 1886 for Izozg, *viâ* Tomina, Tacupaya, Padilla, and Lagunillas, following the course of the river Parapiti, to the heights of Iguiasiriri; from thence they travelled northwards to Carumbei. The march was here impeded for some months by an impenetrable forest of hardwood trees intertwined with thorns, brambles, and cactus; water and pasture were extremely scarce. In the meantime he explored the course of the Parapiti above Carumbei as far as the beautiful lake Ancararenda, and the whole of the Chaco Central and the Chaco Boreal in the province of Chiquitos.

Crossing the mountains of Machareti the party travelled E.N.E. to Puerto Pacheco, but owing to the scarcity of water they were obliged to go southward. In this inhospitable region, situated under the twentieth parallel thirty leagues from the river Paraguay, they pushed on despairingly against the wild opposing forces of nature, exhausted by fatigues and privations of all kinds. Harassed by the Tapihetes Indians they were on the point of succumbing, when M. Thouar and his three companions were rescued by Colonel Martinez, commander of the Bolivian frontier, on the evening of October 1, 1887. They returned to the colony of Crevaux without having been able to reach Puerto Pacheco. This journey lasted from November 1886 to May 1888.

M. Thouar, by a series of daily observations carefully taken, has obtained the following data:—1. The map of his journey on a large scale from Tarija to Asuncion *viâ* the Pilcomayo. 2. A general hydrographical map of the river Pilcomayo with its numerous windings, drawn to a scale of $\frac{1}{400000}$. 3. A relief map, measuring 1 mètre 23 centimètres by 1 mètre 17 centimètres on a scale of $\frac{1}{1000000}$, containing his four journeys.

The Geographical Society of Paris is now completing the publication of these maps.

The eastern Bolivian Andes towards the west present a sombre appearance, and are devoid of vegetation. The central part of the summit towards the east, near the Cordillera de los Frailes, is occupied by an immense elliptical tableland, surrounded by glaciers extending from the north to the gigantic volcanoes of Sorata and Illimani, overlooking the majestic Lake Titicaca. The sky here is incomparably brilliant. The tinkling of bells in a slight cloud of dust, indicating the passage of a flock of llamas loaded with small sacks of copper ore from Oruro, is the only sign of human industry. The huts and villages, which are frequently met with, have a dusty, miserable, dull appearance, and a covering of volcanic ashes conceals the richness of the mines. Vegetation is very scanty, and it is doubtful if the Aymaras and the Quichuas succeed in obtaining even a scanty crop.

Passing the Livichucho volcano, the scene changes, and we enter the second chain. Leaving by degrees the high plateau, and descending the eastern Bolivian slope, we enter the steppes, rich in all sorts of produce, leading to the vast plains of the Chaco. On the right is Potosi, with its famous mines, Huanchaca, Lipez, and Guadalupe; to the left Cochabamba, with its superb valleys; to the north Chuquisaca, the capital, with its great silver mines at Colquechacha; and on the south San Lucas, Cinti, and Taruja, with their beautiful valleys and forests. Beyond these are the last undulations of the Andes, terminating in the vast Chaco plains, extending like a limitless ocean. The Chaco, lying between the 18th and 30th parallels S. latitude and 63° and 57° W. of Greenwich, is divided into three sections. The first, towards the north, is called the Chaco Boreal, and is situated between Chuquitos and the Pilcomayo. The second, constituting the

Chaco Central, is between the rivers Pilcomayo and Bermejo. The third, to the south, is the Chaco Austral, and lies between the rivers Bermejo and Salado. It is an immense sandy formation, sloping from N. to S. and from W.N.W. to E.S.E, the depression being about 200 mètres between Caiza and Formosa. It is drained from W.N.W. to E.S.E. by the Pilcomayo and the Bermejo, two great arteries of the La Plata.

The Pilcomayo takes its rise in the high Bolivian plateau in the vicinity of Potosi, then, running S.S.E. as a rapid and impetuous torrent, is enlarged by a number of affluents, and then takes a precipitous course through a plain having a fall of 21 centimètres per mètre, and, rushing through masses of jasper, freestone, and schists, which form the rocks of Aguaragui and Caipipendi, enters the Chaco at San Francisco de Solano. The current runs at the rate of 1½ to 2 miles per hour, rendering navigation difficult; but at certain places, notably at Cavaya Ropoli, a little below the Crevaux colony, the banks open out and the current flows round innumerable islands.

Bolivia has established missions of Italian Franciscan friars at Machareti, Tiguipa, Tarairi, San Francisco, and Aguarrenda. At this point we reach the limit of civilisation, and passing northwards we enter Izozog, inhabited by the Tapuis Indians, who dwell on the banks of the river Parapiti at Carumbei, Guandare, Ipahuasu, Amenati, Aguarati, Tamane, Tobi, Cobei, Iguiasiriri, Tapere, &c., &c. This group belongs to the tribe of Chiriguanos, who extend along the whole of the missions as far as Caiza and Yacuiva. Immediately to the south are the Matacos at Tonono and Itiyuru. In the thickest part of the forest in the Chaco Boreal dwell the Sirionos, Itirucommbre, the 'En Pelotas,' so called because they are entirely naked, and are in a state of absolute savagery. They live almost exclusively on honey, which is very plentiful, and drink, in the absence of water, from a plant belonging to the *Cruciferæ* family growing very profusely, and called by the Tapins the *Cipo-hi*, from *Cipo* plant, *hi* water. The whole of the left bank of the Pilcomayo is inhabited by the Tobas, Choitis, and Tapihetes Indians. These Indians, whose numbers are very considerable, form three different groups, to judge from their dialects and customs.

On the right bank are the Matacos, the Guimages, with some of the Tobas; these also form three distinct groups, less numerous but more tractable. The Indians who massacred the members of the Crevaux mission in April 1882, belonged to the Tobas, a very vindictive and sanguinary tribe.

On account of its impenetrable forests and the aridity of its sandy soil, the Chaco Boreal cannot be utilised except for its timber, and the *quebracho*, for its enormous quantity of bees-wax and honey deposited in its trunk. M. Thouar, from a careful estimate made from various parts of the Chaco Boreal, calculates that the average quantity of wax and honey that could be collected annually from this region amounts to between 560,000 and 600,000 cwts. The surface of the Chaco Central differs from the Chaco Boreal in being more open, and possessing extensive prairies affording excellent pasturage lands interspersed with well-timbered lands. The Indians living in this district possess numerous flocks of cattle, sheep, goats, horses, and mules.

As regards the Chaco Austral, it is well known that the best colonies to the north of Santa Fé are situated in this region; the climate is highly salubrious, the soil is extremely fertile, and affords abundant scope for agriculture and cattle rearing. The whole of the territory lying between the Pilcomayo to the north and the Salado to the south is most suitable to colonisation, and is destined to become at some future day the granary of South America. The attention of the Bolivian and Argentine Governments has been directed towards the development of this region.

An examination of the map of South America will satisfy anyone that this part of Bolivia cannot be brought into direct communication with Europe by the Chilian route *viâ* Huanahuaca and Antofogasta, or the Peruvian route *viâ* Puno and Mollendo. On the other hand, a route across the Chaco Central by way of the Pilcomayo, or, as has been mooted, a railway between Formosa and Caiza, would bring the extensive and fertile region within eight days' journey of Buenos

Ayres. This suggested route would afford an expeditious outlet for its immensely varied products—gold, silver, bismuth, mercury, marble, all kinds of agricultural produce, &c., &c., and at the same time greatly facilitate the colonisation of Eastern Bolivia.

TUESDAY, SEPTEMBER 9.

The following Papers were read:—

1. *Notes on a Journey in the Eastern Carpathians.*
By Miss MENÉ MURIEL DOWIE.

Miss Dowie read a paper dealing with her experiences among the people who inhabit the Carpathian Mountains on the Eastern or Polish side. She gave a brief description of the life of these people, their work, costume, and character, and included an account of her journeys, alone, on horseback there, the mountains, and the conditions under which she was obliged to live. She concluded with some remarks upon the future of Galicia and its great natural resources in the shape of petroleum wells, salt and silver mines, together with the immense industries in connection with its woods, yet to be fully developed.

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2. *The Present State of the Ordnance Survey and the Paramount Necessity for a Thorough Revision.*[1] HENRY T. CROOK, *C.E.*

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3. *Ancient Maps of Egypt, Lake Moeris, and the Mountains of the Moon*
By COPE WHITEHOUSE.

The revised (1890) map of Middle Egypt prepared by the Intelligence Department of the War Office shows a part of the changes effected by the observations of the author of this paper. A critical study of the manuscript and printed maps attached to the text of Claudius Ptolemy had enabled him to aver, as a crucial test of their authenticity, that a depression would be found to exist in the desert to the west of the Nile, to the south of the Fayoum, with its western extremity nearly south of Alexandria, due south of the Natron lakes, between the latitudes of Heracleopolis and Oxyrhinchus, or (approximately) of Beni-Suef and Maghagha, of a peculiar shape, somewhat resembling a clover-leaf and stem, with remains of a Greek town at the north end of the narrow southern valley, on the east side. The physical conditions of this region have now been determined with extreme accuracy. The map exhibited received the approval of the International Jury at the Paris Exposition (1889), *médaille d'argent*, and has been used by the War Office (1890). The most important maps of the printed editions of Cl. Ptolemy, of the sixteenth and seventeenth centuries, have been reproduced in the facsimile atlas (1890) prepared with great erudition and skill by Baron A. E. Nordenskiold, translated by Mr. Clements R. Markham, C.B., F.R.S. [*Maps exhibited.*] The oldest known manuscript is that of Mt. Athos—possibly of the twelfth century. [*Exhibited in photographic reproduction.*] The most accurate delineation of this region is in the so-called 'Agnese' (Palmese), xvii. 29, A.D. 1554 (photographed by Organia). A comparison shows that the Meridis Lacus, as it was in A.D. 150, exactly corresponds to the Wadi Raiyān and Wadi Muellah, with the ruins of the Deir Muellah, at the contour of high-Nile; or to that regulating reservoir, with an area of 250 square miles and a depth of 220 feet, which will be formed by putting this depression in communication with the Nile.

Mr. H. M. Stanley's identification of Ruwenzori with the Mountains of the Moon reversed this method. He found the mountains, and then examined the

[1] Printed in full in the *Proc. R.G.S.* vol. xii. p. 674.

maps and the historical evidence. The result is the same. The existence of ancient originals from which the mediæval copies were made is no longer open to dispute. They have never been subjected to critical analysis. It is reasonable to anticipate other important additions to geographical knowledge as the result of the renewed credit which will henceforth attach to the only atlas which has reached us from ancient days.

4. *Some Points in connection with Ptolemaic Geography and Ptolemaic Maps.*[1] *By* Dr. SCHLICHTER.

Dr. Schlichter sought to show by comparison of the positions given in Ptolemy's geography that that geographer must have had trustworthy information concerning North-east Africa, the Central Lakes, and the neighbouring mountains.

5. *The actual State of the Question of the Initial Meridian for the Universal Hour.* *By* C. TONDINI DE QUARENGHI.

6. *On recent Explorations in New Guinea.*[2] *By* COUTTS TROTTER, *F.R.G.S.*

7. *Honduras (Spanish).*[3] *By* WILLIAM PILCHER, *F.R.G.S.*

The writer visited the country December 1889, leaving it the end of February 1890, and during that period travelled on muleback over 1,000 miles, chiefly through that part of the country lying on the Pacific side of the Cordilleras, which mountain range forms the backbone of the Central American continent.

From Amapala, the Pacific port, to Tegucigalpa, the capital, from thence to Juticulpa, in Olancho, then to Comayagua (the ancient capital), and the famous silver mines of Opoteca, then to Yuscaran, in El Paraiso, another mining district, back again by another route to Olancho, and finally journeying again from Blancho through the capital to Amapala, and from there to La Union, Salvador, where the Pacific mail steamer was picked up, gives a brief outline of the country traversed.

This comprises the well-known rivers Guayape and Jalan, in Olancho, where the gold-washing provides an easy living for the natives, an inspection of the old Spanish mines at Opoteca and Yuscaran, and at the latter place of the mining camps of the Americans and Germans now in full work, and in addition takes the traveller through and over the beautiful and fertile valleys and plateaus of this country, where tropical vegetation abounds, and coffee, rice, maize, sugar-cane, bananas, plantains, saccate, guavas, oranges, lemons, and other fruits are continuously produced without fear of frosts or adverse seasons. Herds of cattle and native horses are scattered over the country.

The paper contained some figures and statements as to cattle raising, the cultivation of coffee, sugar-cane, and tropical fruits.

8. *On a Visit to the Skaptor District of Iceland.* *By* Dr. TEMPEST ANDERSON *and* Dr. JOHNSTON-LAVIS.

[1] Printed in *Proc. R.G.S.* vol. xiii.
[2] See *Proc. R.G.S.* vol. xii. p. 687.
[3] See *Scottish Geographical Magazine*, vol. vi.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION—Professor ALFRED MARSHALL, M.A., F.S.S.

THURSDAY, SEPTEMBER 4.

The PRESIDENT delivered the following Address:—

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public opinion as an economic force, especially in cases in which effective competition is impossible, or has been displaced by combinations.

§ 19. The difficulties of public opinion, and the importance of its being trained for its new responsibilities.

§ 20. Conclusion.

Some Aspects of Competition.

§ 1. I UNDERSTAND that the function of an Opening Address to a section of this Association is to give an account of the advances made in some part of the field of study with which that section is specially concerned. The part of our field to which I would direct your attention to-day is the action of competition in trade and commerce. We cannot, in the short space of time allotted to us, make an adequate study of the progress that has been made even in this part of our field; but we may be able to go some way towards ascertaining the character of the changes that are going on in our own time in the mode of action of competition, and in the attitude of economists towards it.

I do not now speak of changes in the moral sentiments of economists with regard to competition—though these, also, are significant in their way—but of changes in their mental attitude towards it, and in the way in which they analyse and reason about its methods of action. Of these changes, the most conspicuous and important is the abandonment of general propositions and dogmas in favour of processes of analysis and reasoning, carefully worked out, and held ready for application to the special circumstances of particular problems relating to different countries and different ages, to different races and different classes of industry.

This movement may, perhaps, best be regarded as a passing onward from that early stage in the development of scientific method, in which the operations of Nature are represented as conventionally simplified for the purpose of enabling them to be described in short and easy sentences, to that higher stage in which they are studied more carefully, and represented more nearly as they are, even at the expense of some loss of simplicity and definiteness, and even apparent lucidity. To put the same thing in more familiar words, the English economists of fifty years ago were gratified, rather than otherwise, when some faithful henchman, or henchwoman, undertook to set forth their doctrines in the form of a catechism or creed; and the economists of to-day abhor creeds and catechisms. Such things are now left for the Socialists.

It has, indeed, been an unfortunate thing for the reputation of the older economists, that many of the conditions of England at the beginning of this century were exceptional, some being transitional, and others, even at the time, peculiar to England. Their knowledge of facts was, on the average, probably quite as thorough as that of the leading economists of England or Germany to-day, though their range was narrow. Their thoroughness was their own, the narrowness of their range belonged to their age; and though each of them knew a great deal, their aggregate knowledge was not much greater than that of any one of them, because there were so few of them, and they were so very well agreed. In these matters we economists of to-day have the advantage over them.

Their agreement with one another made them confident; the want of a strong opposition made them dogmatic; the necessity of making themselves intelligible to the multitude made them suppress even such conditioning and qualifying clauses as they had in their own minds: and thus, although their doctrines contained more that was true, and new, and important than those promulgated by almost any other set of men that have ever lived—doctrines for which they will be gratefully remembered as long as the history of our century retains any interest—yet, still, these doctrines were so narrow and inelastic that, when they were applied under conditions of time and place different from those in which they had their origin, their faults became obvious and created a reaction against them.

Perhaps the greatest economic danger of our age is that this reaction may be carried too far, and that the great truths which lie embedded in their too large utterances may be neglected because they are not new, and men are a little tired of them, and because they are associated with much that is not true, and which has become, not altogether unjustly, repugnant to men's sentiments. I propose to illustrate this danger chiefly by reference to that point at which it seems to assume the gravest form just at present, viz., the relations between competition and combination in domestic trade. But the relations between Protection and Free Trade in foreign commerce have a longer and more fully developed history; and I will begin by referring briefly to them, because they throw a clear light both on recent changes in the methods of economic thought, and on the warnings which the experience of our forefathers in dealing with the problems of their age gives us with reference to those problems which are more specially ours.

§ 2. It is a constant source of wonder to Englishmen that Protection survives and thrives, in spite of the complete refutations of Protectionist arguments with which English economists have been ready to supply the rest of the world for the last fifty years or more. I believe that these refutations failed chiefly because some of them implicitly assumed that whatever was true as regards England was universally true; and if they referred at all to any of the points of difference between England and other countries, it was only to put them impatiently aside, without a real answer to the arguments based on them. And further, because it was clearly to the interests of England that her manufactures should be admitted free by other countries, therefore, any Englishman who attempted to point out that there was some force in some of the arguments which were adduced in favour of Protection in other countries, was denounced as unpatriotic. Public opinion in England acted like the savage monarch who puts to death the messenger that comes running in haste to tell him how his foes are advancing on him; and when John Stuart Mill ventured to tell the English people that some arguments for Protection in new countries were scientifically valid, his friends spoke of it in anger—but more in sorrow than in anger—as his one sad departure from the sound principles of economic rectitude. But killing the messengers did not kill the hostile troops of which the messengers brought record; and the arguments which the Englishmen refused to hear, and therefore never properly refuted, were for that very reason those on which Protectionists relied for raising a prejudice in the minds of intelligent and public-spirited Americans against the scientific soundness and even the moral honesty of English economics.

The first great difficulty which English economists had, in addressing themselves to the problems of cosmopolitan economics, arose from the fact that England was an old country—older than America in every sense, and older than the other countries of Europe in this sense, that she had accepted the ideas of the new and coming industrial age more fully and earlier than they had. In speaking of England, therefore, they drifted into the habit of using, as convertible, the two phrases—'the commodities which a country can now produce most easily,' and 'the commodities which a country has the greatest natural advantages for producing,' that is, will always be able to produce most easily. But these two phrases were not approximately convertible when applied to other countries; and when List and Carey tried to call attention to this fact, Englishmen did little more than repeat old arguments, which implicitly assumed that New England's inability to produce cheap calico had the same foundation in natural laws as her inability to produce cheap oranges. They refused fairly to meet the objection that arguments which prove that nothing but good can come from a constant interchange of goods between temperate and tropical regions, do not prove that it is for the interest of the world that the artisans who are fed on American grain and meat should continue always to work up American cotton for American use three thousand miles away. Finding that their case was not fairly met, the Protectionists naturally thought it stronger than it was, and honestly exaggerated it in every way. One of my most vivid recollections of a visit I made, in 1875, to study American Protection on the spot, is that of Mr. Carey's splendid anger, as he exclaimed that foreign commerce had made even the railways of America run from east to west, rather than from north to south.

England had passed through the stage of having to import her teachers from other lands. But her genius for freedom had attracted to her shores the pick of the skilled artisans of the world; she had received the best lessons from the best instructors, and seldom paid them any fee, beyond a safe harbour from political and religious persecution. And modern Englishmen could not realise, as Americans, and even Germans, could fifty years ago, the difficulties of a manufacturer taking part in starting a new industry, when he came to England to beg or steal a knowledge of the trade, and to induce skilful artisans to come back with him. He seldom got the very best; for they were sure of a comfortable life at home, and were perhaps not without some ambition of rising to be masters themselves. He had to pay their travelling expenses, and to promise them very high wages; and when all was done, they often left him to become the owners of the 160 acres allotted to every free settler; or, the bitterest pill of all, they sold their skill to a neighbouring employer who had been looking on at the experiment, and, as soon as it showed signs of prosperity, stepped in, improved on the first experiments, and reaped a full harvest on a soil that had been made ready by others.

Again, the pioneer manufacturer had to bring over specialised machinery, and specialised skill to take care of it. If any part went wrong, or was superseded, the change cost him ten times as much as his English competitor. He had to be self-sufficing: he could get no help from the multitude of subsidiary industries, which in England would have lent him aid at every turn. He had a hundred pitfalls on every side: if he failed, his failure was full of lessons to those who came after; if he succeeded, the profits to himself would be trivial as compared with those to his country. When he told the tale of his struggles, every word went home to his hearers; and when the English economists, instead of setting themselves to discover the best method by which his country might help him in his experiment, said he was flying in the face of Nature, and called him a selfish schemer for wanting any help at all, they put themselves out of court.

§ 3. But the failure of English economists to allow for the special circumstances of new countries did not end here. They saw that Protective taxes in England had raised the price of wheat by their full amount (because the production of wheat obeys the Law of Diminishing Return; and in an old country, such as England, increased supplies could be raised only at a more than proportionately increased cost of labour); that the high price of bread had kept a large part of the population on insufficient rations; that it had enriched the rich at the expense of a much greater loss to the rest of the nation; and that this loss had fallen upon those who were unable to lose material wealth without also losing physical, and even mental and moral strength; and that even those miseries of the overworked factory women and children, which some recent German writers have ascribed exclusively to recklessness of manufacturing competition in its ignorant youth, were really caused chiefly by the want of freedom for the entry of food. They were convinced, rightly, as I believe, that the benefits claimed for Protection in England were based, without exception, on false reasoning; and they fought against it with the honest, but also rather blind, energy of a religious zeal.

Thus they overlooked the fact that many of those indirect effects of Protection which aggravated then, and would aggravate now, its direct evils in England, worked in the opposite direction in America. For, first, the more America exported her raw produce in return for manufacture, the less the benefit she got from the Law of Increasing Return as regards those goods that she manufactured for herself; and thus her case was contrasted with England, who could manufacture them more cheaply for her own use the more of her manufactures she sent abroad to buy raw produce; and for this and other reasons, a Protective tax did not nearly always raise the cost of goods to the American consumer by its full amount. And, secondly, Protection in America did not, as in England, tax the industrial classes for the benefit of the wealthy class of landlords. On the contrary, in so far as it fell upon the exporters of American produce, it pressed on those who had received large free gifts of public land; and there was no *primâ facie* injustice in awarding to the artisans, by special taxation, a small part of the fruits of that land, the direct ownership of which had not been divided between farmers and artisans, as it equitably might have been, but had been given exclusively to the former.

§ 4. I have touched on but a few out of many aspects of the problem. But perhaps I may stop here, and yet venture to express my own opinion on the controversy. It is, that fifty years ago it might possibly have been not beyond the powers of human ingenuity to devise schemes of Protection which would, on the whole, be beneficial to America, at all events if one regarded only its economic and neglected its moral effects; but that the balance has turned strongly against Protection long ago. In 1875 I visited America, discussed the Protective policy with several of its leading advocates, visited some of the factories in almost every first-class city, and compared as well as I could the condition of the workers there with that of similar workers at home; and lastly I walked up and down the streets and said to myself as I went, The adoption of Free Trade, so soon as its first disturbances were over, would strengthen this firm, and weaken that; and I tried to strike a rough balance of the good and evil effects of such a change on the non-agricultural population. On the whole, it seemed to me the two were about equally balanced; and that those which would be likely to lose by the abandonment of Protection were not the higher, but rather the lower, classes of manufacturing industries: for instance, those metal and wood trades which give the best scope for the special genius of the native American artisan would gain by the change. Taking account, therefore, of the political corruption which necessarily results from struggles about the tariff in a democratic country, and taking account also of the interests of the agricultural classes, I settled in my own mind the question as to which I had kept an open mind till I went to America, and decided that, if an American, I should unhesitatingly vote for Free Trade. Since that time the advantages of Protection in America have steadily diminished, and those of Free Trade have increased; I can see no force in Professor Patten's new defence of Protection as a permanent policy. I have already implied that I believe that many of those arguments that tell in favour of Protection as regards a new country, tell against it as regards an old one. Especially for England a Protective policy would, I believe, be an unmixed and grievous evil.

§ 5. But this expression of my own opinion is a digression. My present purpose in discussing Protection is to argue that, if the earlier English economists had from the first studied the conditions of other countries more carefully, and abandoned those positions that were at all weak, they could have retained the controversy with their opponents within those regions where they had a solid advantage. They would thus have got a more careful hearing when they claimed that, even though labour migrated more freely between the west and the east of America than between England and America, yet it was unwise to spend so much trouble on protecting the nascent industries of the East against those of England, and none on protecting the nascent industries of the West against those of the East; or, again, when they urged that, the younger an industry was, and the more deeply it needed help, the more exclusively would its claims have to stand on its own merits; while its older and sturdier brothers could supplement their arguments by a voting power which even the most honest politicians had to respect, and by a power of corruption which would tend to make politics dishonest.

Had the English economists been more careful and more many-sided, they would have gradually built up a prestige for honesty and frankness, as well as for scientific thoroughness, which would have inclined the popular ear to their favour, even when their arguments were difficult to follow. Intellectual thoroughness and sincerity is its own reward; but it is also a prudent policy when the people at large have to be convinced of the advisability of a course of action against which such plausible fallacies can be urged as that 'Protection increases the employment of domestic industries,' or that 'it is needed to enable a country in which the rate of wages is generally high to carry on trade with another in which it is generally low.' The arguments by which such fallacies can be opposed have an almost mathematical cogency, and will convince, even against his will, anyone who is properly trained for such reasonings. But the real nature of foreign trade is so much disguised by the monetary transactions in which it is enveloped, that a clever sophist has a hundred opportunities of throwing dust in the eyes of ordinary people, and especially the working-classes, when urging the claims of Protection as affording a short cut to national prosperity; and, to crown all, he contrasts America's prosperity with English prophecies of the ruin that Protection would bring on her.

It is true that Ricardo himself, and some of those who worked with him, were incapable of supposing that a doctrine can be made more patriotic by being made less true; and, so far as their limits went, they examined the good and evil of any proposed course, and weighed the good and evil against one another in that calm spirit of submissive interrogation with which the chemist weighs his materials in his laboratory. But they were few in number, and their range of inquiry was somewhat narrow; while many of those Englishmen who were most eager to spread Free Trade doctrines abroad had not the pure scientific temper.

Now at length, however, there seems to be the dawn of a brighter day in the growth of large numbers of many-sided students, in England and other countries, and notably in America itself, where the problems of Protection can be studied to most advantage—students who are not, indeed, without opinions as to what course it is most expedient to follow practically, but who are free from party bias, and have the true scientific delight in ascertaining a new fact or developing a new argument, simply because they believe it to be new and true, and who welcome it equally whether it tells for or against the practical conclusion which, on the whole, they are inclined to support.

§ 6. But I must leave the subject of competition from outside a nation, and pass to that of competition within. Here the past counts for less; the present and the future have to work for themselves without very much direct aid from experience. For, rapid as are the changes which the last few years have seen in the conditions of foreign trade, those which are taking place in the relations of different groups of industry within a country are more rapid still, and more fundamental. The whirligig of Time brings its revenges. It was to England's sagacity and good fortune in seizing hold of those industries in which the Law of Increasing Return applies most strongly that she owed in a great measure her leading position in commerce and industry. Time's revenge was that that very Law of Increasing Return furnished the chief motive to other countries, and especially America, to restrict their commerce with her by Protective duties to home industries. And Time's counter-revenge is found in this—that England's Free Trade has prevented the Law of Increasing Return from strengthening combinations of wealthy manufacturers against the general weal here to the same extent as it has in countries in which Protection has prevailed, and notably America.

The problem of the relations between competition and combination is one in which differences of national character and conditions show themselves strongly. The Americans are the only great people whose industrial temper is at all like that of the English; and yet even theirs is not very like. Partly because of this difference of temper, but more because of the differences in the distribution of wealth and in the physical character of the two countries, the individual counts for much more in American than in English economic movements. Here, few of those who are very rich take a direct part in business; they generally seek safe investments for their capital; and again, among those engaged in business the middle class predominates, and most of them are more careful to keep what they have, than eager to increase it by risky courses. And lastly, tradition and experience are of more service and authority in an old country than in one which, like America, has not yet even taken stock of a great part of her natural resources, and especially those mineral resources, the sudden development of some of which has been the chief cause of many recent dislocations of industry.

In England, therefore, the dominant force is that of the average opinion of business-men; and the dominant form of association is that of the joint-stock company. But in America the dominant force is the restless energy and the versatile enterprise of a comparatively few very rich and able men, who rejoice in that power of doing great things by great means that their wealth gives them; and who have but partial respect for those who always keep their violins under glass cases. The methods of a joint-stock company are not always much to their mind; they prefer combinations that are more mobile, more elastic, more adventurous, and often more aggressive. For some purposes they have to put up with a joint-stock company; but then they strive to dominate it, not be dominated by it. Again, since distances in America are large, many local monopolies are possible in America which are not possible in England; in fact, the area of a local monopoly there is often greater than that of the whole of England. A local coal combination, for instance, means quite a different thing there from what it does in England, and is more powerful every way.

Again, partly, but not solely, because they are so much in the hands of a few wealthy and daring men, railways, both collectively and individually, are a far greater power in America than in England. America is the home of the popular saying that, if the State does not keep a tight hand on the railways, the railways will keep a tight hand on the State; and many individual railways have, in spite of recent legislation, a power over the industries within their territories such as no English railway ever had: for the distances are great, and the all-liberating power of the free ocean befriends America but little.

It is this change of area that is characteristic of the modern movement. In Adam Smith's time England was full of trade combinations, chiefly of an informal kind, indeed, and confined to very narrow areas; but very powerful within those areas, and very cruel. Even at the present day, the cruellest of all combinations in England are, probably, in the trades that buy up small things, such as fish, and dairy and garden produce, in detail, and sell them in retail; both producers and consumers being, from a business point of view, weak relatively to the intermediate dealers. But even in these trades there is a steady increase in the areas over which such combinations and partial monopolies extend themselves. New facilities of transport and communication tell so far on the side of the consumer, that they diminish the *intensity* of the pressure which a combination can exert; but, at the same time, they increase the *extension* of that pressure, partly by compelling, and partly by assisting, the combination to spread itself out more widely. And in England, as in other Western countries, more is heard every year of new and ambitious combinations; and of course many of them remain always secret.

But it is chiefly from America that a cry has been coming with constantly increasing force for the last fifteen years or more, that in manufactures free competition favours the growth of large firms with large capitals and expensive plants; that such firms, if driven into a corner, will bid for custom at any sacrifice; that, rather than not sell their goods at all, they will sell them at the Prime Cost—*i.e.*, the actual outlay required for them, which is sometimes very little; that, when there is not enough work for all, these manufacturers will turn their bidding recklessly against one another, and will lower prices so far that the weaker of them will be killed out, and all of them injured; so that when trade revives they will be able, even without any combination among themselves, to put up prices to a high level; that these intense fluctuations injure both the public and the producers; and the producers, being themselves comparatively few in number, are irresistibly drawn to some of those many kinds of combinations to which, nowadays, the name Trust is commonly, though not quite accurately, applied; and that, in short, competition burns so furiously as to smother itself in its own smoke. It is a Committee of the American Congress that reports that 'combination grows out of, and is the natural development of, competition, and that in many cases it is the only means left to the competitors to escape absolute ruin.'

The subject is one on which it would be rash to speak confidently. We of this generation, being hurried along in a whirl of change, cannot measure accurately the forces at work, and it is probable that the best guesses we can make will move the smiles of future generations; they will wonder how we could have so much over-estimated the strength of some, and under-estimated the strength of others. But my task is to try to explain what it is that economists of this generation are thinking about competition in relation to combination; and I must endeavour to reproduce their guesses, hazardous though this may be.

§ 7. To begin with, I think that it is the better opinion that popular rumour, going now as ever to extremes, has exaggerated some features of the movement towards combination and monopoly, even in America. For instance, though it is said that there are a hundred commodities the sale of which in America is partly controlled by some sort of combination, many of these combinations turn out to be of small proportions, and others to be weak and loose. Again, the typical instances which are insisted on by those who desire to magnify the importance of the movement are nearly always the same, and they have all had special advantages of more or less importance.

This is specially true of the only Trust which can show a long record of undisputed success on a large scale—the Standard Oil Trust. For, firstly, the petroleum in which it deals comes from a few of Nature's storehouses, mostly in the same neighbourhood: and it has long been recognised that those who can get control over some of the richest natural sources of a rare commodity are well on their way towards a partial monopoly. And, secondly, the Standard Oil Trust has many of those advantages which have been long recognised as enabling large railway companies to get the better of their smaller neighbours; for, directly or indirectly, it has in some measure controlled the pipe lines and the railways which have carried its oil to the large towns and to tidal water.

§ 8. On the other hand, we must remember that the future of a young and vigorous movement is to be measured, not so much by what it has achieved, as by what it has learnt; and that every unsuccessful attempt to hold together a Trust has been a lesson as to what to avoid, taught to men who are wonderfully quick to learn. In particular, it is now recognised that a very large portion of the failures in the past have been due to attempts to charge too high a price; that this high price has tempted those on the inside to break faith, and has tempted those on the outside to start rival works, which may bleed the Trust very much unless it consents to buy them up on favourable terms; and, lastly, that this high price irritates the public: and that, especially in some States, public indignation on such matters leads to rapid legislation that strikes straight at the offenders, with little care as to whether it appears to involve principles of jurisprudence which could not be applied logically and consistently without danger. The leaders in the movement towards forming Trusts seem to be resolved to aim in the future at prices which will be not very tempting to anyone who has not the economies which a large combination claims to derive, both in producing and in marketing, from its vast scale of business and its careful organisation; and to be content with putting into their own pockets the equivalent of these economies in addition to low profits on their capital. There are many who believe that combinations of this kind, pursuing a moderate policy, will ultimately obtain so great a power as to be able to shape, in a great measure, the conditions of trade and industry.

§ 9. It may be so, but these eulogists of Trusts seem to claim for them both that individual vigour, elasticity, and originating force which belong to a number of separate firms, each retaining a true autonomy, and that strength and economy which belong to a unified and centralised administration. Sanguine claims of this kind are not new; they have played a great part in nearly all the bold schemes for industrial reorganisation which have fascinated the world in one generation after another. But in this, their latest form, they have some special features of interest to the economic analyst.

They have a certain air of plausibility. for the organisers of Trusts claim that they see their way to avoiding the weak points in ordinary forms of combination among traders, which consist in the fact that their agreements can generally be evaded without being broken. For instance, the most remarkable feature in the history of English railways during the present generation is, not their tendency to agree on the fares and freights to be charged over parallel lines—for that has long been a foregone conclusion—it is the marvellously effective competition for traffic which such railways have maintained, both of a legitimate kind, by means of improved conveniences offered to the public as a whole, or of an illegitimate kind, by means of those special privileges to particular traders which we are now, at last, seriously setting ourselves to stop by law.

It is difficulties of this kind which the modern movement towards Trusts aims specially at overcoming. Trusts have very many forms and methods, but their chief motive in every case is to take away from the several firms in the combination all inducements to compete by indirect means with one another.[1] The chief

[1] P.S.—Professor Brentano has called my attention to the plan of the German Iron Combination, which does not allow individual firms to sell direct to the consumer, but

instrument for this purpose is usually some plan for pooling their aggregate receipts, and making the gains of each depend on the gains of all, rather than on the amount of business it gets for itself. But her e the dilemma shows itself. If each establishment is left to its own devices, but has very little to lose by bad management, it is not likely long to remain well managed, and anyhow the Trust does not gain much of the special economy resulting from production on a very large scale. For this a partial remedy can sometimes be found in throwing as much of its work as possible on to those establishments which are best situated, have the best and most recent appliances and the ablest management; and perhaps in closing entirely some of the others. But when once the pooling has begun, the combination is on an inclined plane, and every step hurries it on faster towards what is virtually complete amalgamation and consolidation. The recent history of Trusts shows a constant tendency to give a more and more absolute power to the central executive and to reduce the heads of the separate establishments more and more nearly to the position of branch managers. In some cases the only substantial difference between such a Trust and a consolidated joint-stock company is that it is nominally left open to the several parties contracting to claim their separate property after the lapse of a certain number of years, while some are already preparing to dissolve and reconstitute themselves formally as joint-stock companies.

§ 10. This tendency has been helped on by the action of the legislature and the law courts, and since this action can be traced back in some measure to the imperfect analysis of competition in the older economic writings, it has a special interest for us here. There seems to have been set up a false antithesis between competition and combination. For instance, if 100 workmen agreed to act together, as far as possible, in bargaining for the sale of their labour, they were denounced as combining to limit freedom, even when they did not interfere in any way with the liberty of other workmen, but merely deprived the employers of the freedom of making bargains with the 100 workmen one by one. But the employer himself was allowed to unite in his own hands the power of hiring a hundred or twenty hundred men, and if he had not enough capital of his own he might take others into private, if not into public, partnership with him. Now, no trades union was likely to be as compact a combination, governed by as single a purpose, as a public or private firm, still less as an individual large employer; and therefore there was not only a class injustice, but also a logical confusion, in prohibiting combinations among workmen, on the ground that free competition was a good, and that combination, being opposed to free competition, was, for that reason, an evil.

It was an additional grievance to the workmen that employers had all manner of facilities for combination, of which they made full use; as is vigorously urged by Adam Smith, to whom the working classes owe more than they know. And it was this social injustice, rather than the logical inconsistency of economists and legislators, that led workmen to claim—and for the greater part successfully—that nothing should be illegal if done by workmen in combination which would not be illegal if done by any one of them separately—a principle which works well practically in the particular case of workmen's combinations if applied with moderation; though it has no better claim to universal validity than the opposite doctrine.

But at present it is with the latter that we are concerned—the doctrine, namely, that a use of the rights of property which would be 'combination in restraint of competition' if the ownership of the property were in many hands, is only a free use of the forms of competition when the property is all in a single hand. This doctrine has resulted in the prohibition of pooling between railways which were allowed to amalgamate, and in the prohibition of combination on the part of a group of traders to coerce others to act with them, or to drive others out of the trade, though all the while no attempt was made to hinder a single very wealthy firm from obtaining the despotic control of a market by similar means.

only through a central office. It fixes the amount of each firm's produce which may be sold, and the price of sale, and each firm gains by every reduction it can make in its own expenses of working. This plan has great elements of strength, and is probably specially suitable for Germany. But it is yet on its trial.

But to the economists of to-day the whole question appears both more complex and more important than it seemed to their predecessors, so they are inquiring in detail how far it is true that the looser forms of combination are specially dangerous in spite of their weakness, and even to some extent because of their weakness; how far the greater stability and publicity, and sense of responsibility and slowness of growth, of a single consolidated firm make it less likely to extend its operations over a very wide area, and less likely to make a flagrantly bad use of its power; and, lastly, how far it may be expedient to prohibit actions on the part of loose combinations, while similar actions on the part of individuals and private firms are allowed to pass in silence, because no prohibition against them could be effectual.

It is a sign of the times that the American Senate approved, on April 8 last, a Bill of Senator Sherman's, of which the second Section begins thus: 'Every person who shall monopolise, or attempt to monopolise, or conspire with any other person or persons to monopolise, any part of the trade or commerce among the several States, or with foreign nations, shall be deemed guilty of a misdemeanour.' This clause is interesting to the constitutional lawyer on account of the skill with which it avoids any interference by the central authority with the internal affairs of the separate States; and though, partly for this reason, it is perhaps intended to be the expression of a sentiment that may help to guide public opinion, rather than an enactment which will bear much direct fruit; yet it is of great interest to the economist as showing a tendency to extend to the action of individuals a form of public criticism which has hitherto been almost confined to the action of combinations.

To return, then, to the tendency of Trusts towards consolidation. It is probable that the special legislative influences by which it has been promoted may be lessened, but that other causes will remain sufficiently strong to make a combination, which has once got so far as any sort of permanent pooling, tend almost irresistibly towards the more compact unity of a joint-stock company. If this be so, the new movement will go more nearly on old lines than at one time seemed probable; and the question will still be the old one of the struggle for victory on the one hand between large firms and small firms, and on the other between departments of the Government, imperial or local, and private firms. I will then pass to consider the modern aspects of this question, ever old and ever new, but never more new and never more urgent than to-day.

§ 11. To begin with, it is now universally recognised that there is a great increase in the number and importance of a class of industries, which are often called monopolies, but which are perhaps better described as *indivisible* industries. Such are the industries that supply gas or water in any given area, for only one such company in any district can be given leave to pull up the streets. Almost on the same footing are railways, tramways, electricity supply companies, and many others. Now, though there are some little differences of opinion among the economists of to-day as to the scale on which the owners of such undertakings when in private hands should be compensated for interference with what they had thought their vested rights, we are all agreed that such right of interference must be absolute, and the economists of to-day are eagerly inquiring what form it is most expedient for this interference to take. And here differences of opinion show themselves. The advantages of a bureaucratic government appeal strongly to some classes of minds, among whom are to be included many German economists and a few of the younger American economists who have been much under German influence. But those in whom the Anglo-Saxon spirit is strongest, would prefer that such undertakings, though always under public control, and sometimes even in public ownership, should whenever possible be worked and managed by private corporations. We (for I would here include myself) believe that bureaucratic management is less suitable for Anglo-Saxons than for other races who are more patient and more easily contented, more submissive and less full of initiative, who like to take things easily and to spread their work out rather thinly over long hours. An Englishman's or an American's life would involve too much strain to make them happy, while the Englishman would fret under the constraints and the small economies of their lives. Without therefore expressing any opinion as to the advantages of the public management of indivisible undertakings on the Continent, the greater part of the younger English and American economists are, I think, inclined to oppose it for England and America. We are not sure that we could exchange our own industrial virtues for those of the Continent if we wished to, and we are not sure that we do wish it. And though we recognise that the management of a vast undertaking by a public company has many of the characteristics of bureaucratic management, yet we think the former is distinctly the better suited for developing those faculties by which the Anglo-Saxon race has won its position in the world. We believe that a private company which stands to gain something by vigorous and efficient management, by promptness in inventing, as well as in adopting and perfecting improvements in processes and organisation, will do much more for progress than a public department.

Again, while a public company is inferior to a small private firm in its power and opportunities of finding out which among its employés have originating and constructive ability, a department of Government is far inferior to a joint-stock company, especially in England. And, further, such a department is more liable to have the efficiency of its management interfered with for the purpose of enabling other persons to gain the votes of their constituents on questions in which it has no direct concern; and as a corollary from this, it tends to promote the growth of political immorality, and it suffers from that growth.

There is certainly a growing opinion among English and American economists that the State must keep a very tight hand on all industries in which competition is not an effective regulator; but this is the expression of a very different tone of thought from that which is leading so many German economists towards what is called State Socialism. In fact, so far as I can judge, English economists at all events are even more averse to State management than they were a few years ago; the set of their minds is rather towards inquiring how the advantages claimed for State management, without its chief evils, can be obtained even in what I have called indivisible industries; they are considering how a resolute intervention on the part of the State may best check the growth of *Imperia in Imperio,* and prevent private persons from obtaining an inordinate share of the gains arising from the development, through natural causes, of what are really semi-public concerns, at the same time that it leaves them sufficient freedom of initiative and sufficient security of gain by using that freedom energetically to develop what is most valuable in the energy and inventiveness of the Anglo-Saxon temper.[1]

But, though we dislike and fear the present tendency towards a widening of the area of public management of industries, we cannot ignore its actual strength. For more forethought and hard work are needed to arrange an effective public control over an undertaking than to put it bodily into the hands of a public department; and there is always a danger that in a time of hasty change the path of least resistance will be followed.

By way of illustration of the inquiries that have had their origin in this fear of public management, as contrasted with public control and public ownership, I would here mention a notion which has been suggested partly by the relations of some municipalities to their tramways, gas and water works. At present it is in a very crude form, and not ready for immediate application; but it seems to have occurred independently to a good many people, and it may have an important future. It is that a public authority may be able to own the franchise and, in some cases, part of the fixed capital of a semi-public undertaking, and to lease them for a limited number of years to a corporation who

[1] Among the younger English economists who have written on the subject of Combinations, Trusts, and Government interference, I would specially refer to Mr. Rae and Professor Foxwell. Most of the other young American economists have written on it instructively from various points of view, and in Mr. Baker's *Monopolies and the People,* to which I am myself much indebted, the English reader will find condensed into a short compass an account of the general position of these questions in America, together with some bold and interesting suggestions for reform. Some useful documents relating to Trusts have recently been published in a Consular Report by our Foreign Office [5896-32].

shall be bound to perform services, or deliver goods, at a certain price and subject to certain other regulations, some of which may perhaps concern their relations to their employés. In order that the plan may have a fair chance of success, it is essential that the capital to be supplied by the private corporation should not be so large as to prevent there being a real and effective competition for the franchise. But this being assumed, the special point of the proposal is that, where possible, the competition for the franchise shall turn on the price or the quality, or both, of the services or the goods, rather than the annual sum paid for the lease. Competition as to quality is, from the consumer's point of view, often just as beneficial as competition as to price, and sometimes more so. And in industries which obey the Law of Increasing Returns, as very many of these indivisible industries do, a reduction of price or an improvement of quality will confer on the consumer a benefit out of all proportion to the extra cost involved.[1]

§ 12. But I have lingered too long over those industries which I have called indivisible, and I must pass to those in which competition exerts a pretty full sway. The first point to be observed is that competition in bargaining and competition in production stand in very different relations to the public interest; and that one of the great advances in modern analysis consists in the emphasis which it lays on the distinction between the two. Competition in bargaining constitutes a great part of competition in marketing, but is not the whole of it. For under marketing is included the whole of the effective organisation of the trade side of a business; and most of this performs essential services for the public, and is, in fact, of the same order as production commonly so called. But a great part of marketing consists of bargaining, of manœuvring to get others to buy at a high price and sell at a low price, to obtain special concessions or to force a trade by offering them. This is, from the social point of view, almost pure waste; it is that part of trade as to which Aristotle's dictum is most nearly true, that no one can gain except at the loss of another. It has a great attraction for some minds that are not merely mean; but nevertheless it is the only part of honest trade competition that is entirely devoid of any ennobling or elevating feature. A claim is made on behalf of large firms and large combinations that their growth tends to diminish the waste, and on the whole perhaps it does. The one solid advantage which the public gain from a combination powerful enough to possess a local monopoly is that it escapes much waste on advertising and petty bargaining and manœuvring. But its weakness in this regard lies in the fact that to keep its monopoly it must be always bargaining and manœuvring on a large scale. And if its monopoly is invaded, it must bargain and manœuvre widely in matters of detail as well as in larger affairs.

Still less can we fully concede, without further proof, the claim which has been urged on behalf of such combinations, that they will render industry more stable and diminish the fluctuations of commercial activity. This claim, though put forward confidently and by many writers, does not appear to be supported by any arguments that will bear examination. On the one hand some industries which are already aggregated into large and powerful units, such as railway companies, give exceptionally steady employment; and others, such as the heavy iron and the chemical industries, exceptionally unsteady. And when combinations succeed in steadying their own trades a very little, they often do it by means which diminish production and disturb other trades a very great deal. The teaching of history seems to throw but little light on the question, because the methods of regulation which are now suggested have not much in common with those of earlier times, while the causes which govern fluctuations in prices have changed their character completely.

§ 13. Let us then next turn to the economies of production on a large scale. They have long been well known, and our forefathers certainly did not underrate their importance. For, though the absence of any proper industrial census in England prevents us from getting exact information on the subject, yet there seems no doubt

[1] This belongs to a class of questions relating to monopolies, &c., the more general and abstract aspects of which can be best shown by the diagrammatic method.

that the increase in the average size of factories has gone on, not faster, but slower than was thought probable a generation or two ago. In many industries, of which the Textile may be taken as a type, it has been found that a comparatively small capital will command all the economies that can be gained by production on a large scale; and it seems probable that in many industries in which the average size of businesses has been recently increasing fast, a similar position of maximum economy will shortly be attained without any much further increase in size.

Those reductions in the expenses of production of commodities which have been claimed by the eulogists of Trusts and other large combinations, as tending to show that their gains are not at the expense of the public, turn out generally to have been at least equalled by the reductions in the expenses of production in similar industries in which there was no combination. And this count in their eulogy, though it may truly stand for something, seems to have been much exaggerated.

§ 14. After all, what these very large public firms and combinations of firms have done has generally been to turn to good account existing knowledge, rather than to increase that knowledge. And this brings us to the main reason for regarding with some uneasiness any tendency there may be towards such consolidations of business. Observation seems to show, what might have been anticipated *à priori*, that though far superior to public departments, they are, in proportion to their size, no less inferior to private businesses of a moderate size in that energy and resource, that restlessness and inventive power, which lead to the striking out of new paths. And the benefits which the world reaps from this originality are apt to be underrated. For they do not come all at once like those gains which a large business reaps by utilising existing knowledge and well-proven economies; but they are cumulative, and not easily reckoned up. He who strikes out a new path by which the work of eight men is rendered as efficient as that of ten used to be, in an industry that employs 100,000 men, confers on the world a benefit equal to the labour of 20,000 men. And this benefit may in many cases be taken as running for many years. For though his discovery might have been made later by someone else of equal inventive power, yet this someone else, starting with that discovery in hand, is likely to make another improvement on it.

I believe that the importance of considerations of this kind is habitually underrated in the world at large; and that the older economists, though fully conscious of them, did not explain with sufficient clearness and iteration the important place which they take in the claims of industrial competition on the gratitude of mankind.

The chemist in his laboratory can make experiments on his own responsibility: if he had to ask leave from others at each step he would go but slowly, and though the officials of a company may have some freedom to make experiments in detail, yet even as regards these they seldom have a strong incentive to exertion; and in great matters the freedom of experimenting lies only with those who undertake the responsibility of the business.

§ 15. It may indeed be admitted that some kinds of industrial improvements are getting to depend on the general increase of scientific knowledge rather than on such experiments as can only be made by business men. In a few cases large firms hire specialists to make experiments in the technical applications of science. But, on the whole, the dependence of an industry on the progress of that scientific knowledge which is at once nationalised, or rather cosmopolitanised, tells on the side of those small firms which have great managing ability in proportion to their capital, but cannot afford to make many expensive experiments for themselves. And these, which are important facts so far as they go, may be used as a convenient introduction to the next point that I want to make in the analysis of competition. It is that the motives which induce business men to compete for wealth are not altogether as sordid as the world in general, and, I am forced to admit, economists in particular, have been wont to assume.

The chemist or the physicist may happen to make money by his inventions, but that is seldom the chief motive of his work. He wants to earn somehow the means of a cultured life for himself and his family, but, that being once provided, he spends himself in seeking knowledge partly for its own sake, partly for the good that it may do to others, and last, and often not least, for the honour it may do himself. His discoveries become collective property as soon as they are made, and altogether he would not be a very bad citizen of Utopia just as he is. For it would be a great mistake to suppose that the constructors of Utopias from the time of Plato downwards have proposed to abolish competition. On the contrary, they have always taken for granted that a desire to do good for its own sake will need to be supplemented by emulation or competition for the approbation of others.

But business men are very much of the same nature as scientific men; they have the same 'instincts of the chase,' and many of them have the same power of being stimulated to great and even feverish exertions by emulations that are not sordid or ignoble. This part of their nature has however been confused with and thrown into the shade by their desire to make money. The chief reason why the scientific man does not care much for money is that in scientific work the earning of much money is no proof of excellence, but sometimes rather the reverse. On the other hand, in business a man's money-earning power, though not an accurate test of the real value to the world of what he has done, is yet often the best available. It is that test which most of those, for whose opinion he cares, believe to be more trustworthy than the highly coloured reports the world hears from time to time of the benefits which it is just going to derive from a new invention or plan of organising that is just going to revolutionise a branch of industry. And so all the best business men want to get money, but many of them do not care about it much for its own sake; they want it chiefly as the most convincing proof to themselves and others that they have succeeded.

§ 16. These are the very men for whom the older economists were most eager to claim freedom of competition as needful to induce them to do fully their high work for the world. But this seems to involve the error of running together, and treating as though they were one, two different positions—an error which appears to resemble, both in its character and in the gravity of its consequences, the neglect to distinguish between the results of Protection in an old and a new country.

The first of these positions is that industrial progress depends on our getting the right men into the right places and giving them a free hand, and sufficient incitement to exert themselves to the utmost; and the second is that nothing less than the enormous fortunes which successful men now make and retain would suffice for that purpose. This last position seems to be untenable.

The present extreme inequalities of wealth tend in many ways to prevent human faculties from being turned to their best account. A good and varied education, freely prolonged to those children of the working classes who showed the power and the will to use it well, an abundance of open-air recreation even in large towns, and other requisites of a wholesome life—such things as these might, most of us are inclined to think, be supplied by taxes levied on the rich, without seriously checking the accumulation of material capital; and with the effect of increasing rather than diminishing the services which competition renders to society by tending to put the ablest men into the most important posts, the next ablest into the next most important, and so on, and by giving to those in each grade freedom sufficient for the full exercise of their faculties.

It is quite true that where any class of workers have less than the necessaries for efficiency, an increase of income acts directly on their power of work. But when they already have those necessaries, the gain to production from a further increase of their income depends chiefly on the addition that it makes, not to their power of working, but to their will to exert themselves. And all history shows that a man will exert himself nearly as much to secure a small rise in income as a large one, provided he knows beforehand what he stands to gain, and is in no fear of having the expected fruits of his exertions taken away from him by arbitrary spoliation. If there were any fear of that he would not do his best; but if the conditions of the country were such that a moderate income gave as good a social position as a large one does now; if to have earned a moderate income were a strong presumptive proof that a man had surpassed able rivals in the attempt to do a difficult thing well, then the hope of earning such an income would offer, to all but the most sordid natures, inducements almost as strong as they are now when there is an equal hope of earning a large one.

§ 17. On all this class of questions modern economists are inclined to go a little way with the Socialists. But all socialist schemes, and especially those which are directly or indirectly of German origin, seem to be vitiated by want of attention to the analysis which the economists of the modern age have made of the functions of the undertaker of business enterprises. They seem to think too much of competition as the exploiting of labour by capital, of the poor by the wealthy, and too little of it as the constant experiment by the ablest men for their several tasks, each trying to discover a new way in which to attain some important end. They still retain the language of the older economists, in which the employer, or undertaker, and the capitalist are spoken of, as though they were, for all practical purposes, the same people. The organ of the German school of English Socialists prints frequently in thick type the question, 'Is there one single useful or necessary duty performed by the capitalist to-day which the people organised could not perform for themselves?' It would be just as reasonable to ask if there is a single victory to which Julius Cæsar or Napoleon conducted their troops, which the troops properly organised could not have equally well won for themselves; or whether there is a single thing written by Shakespeare which could not have been equally well written by anyone else who, as Charles Lamb said, happened to 'have the mind to do it.' It is quite true that many business men earn large incomes by routine work. It is just in these cases that Co-operation can dispense with middlemen and even employers. But the German Socialists have been bitter foes of Co-operation; though this antagonism is less than it was.

The world owes much to the Socialists, as it does to every set of enthusiasts among whom there are honest men; and many a generous heart has been made more generous by reading their poetic aspirations. But before their writings can be regarded as serious contributions to economic science, they must make more careful and exact analysis of the good and the evil of competition. They must suggest some reasonably efficient substitute for that freedom which our present system offers to constructive genius to work its way to the light, and to prove its existence by attempting difficult tasks on its own responsibility, and succeeding in them; for those who have done most for the world have seldom been those whom their neighbours would have picked out as likely for the work. They must not, as even Mr. Bellamy and other American Socialists do, in spite of their strong protestations to the contrary, assume implicitly a complete change of human nature, and propound schemes which would much diminish the aggregate production, but which they represent as enabling every family to attain an amount of material well-being which would be out of reach of the aggregate income if England or America were divided out equally among the population.

§ 18. But though the Socialists have ascribed to the virtues inherent in the human breast, and to the regulating force of public opinion, a much greater capacity for doing the energising work of competition than they seem really to have; yet, unquestionably, the economists of to-day do go beyond those of earlier generations in believing that the desire of men for the approval of their own conscience, and the esteem of others, is an economic force of the first order of importance, and that the strength of public opinion is steadily increasing with the increase and the diffusion of knowledge, and with the constant tendency of what had been regarded as private and personal issues to become public and national.

Public opinion acts partly through the Government. But though the enforcement of the law in economic matters occupies the time of a rapidly increasing number of people; and its administration is improving in every way, it fails to keep pace with the demands resulting from the growing complexity of economic organisation, and the growing sense of responsibility of public opinion. A part of this failure is due to a cause which might easily be remedied; it is that the adjustment of punishment to offences is governed by traditions descending from a time when the economic structure of England was entirely different. This is most conspicuous with regard to the subtler, or, as they are sometimes called with unconscious irony, the more gentlemanly forms of commercial fraud on a large scale; for which the punishment awarded by the law courts is often trivial in comparison with the aggregate gains which the breakers of the law, whose offences can seldom be proved, make by their wrongdoing; and it is still more trivial in comparison with the aggregate injury which such wrongdoing inflicts on the public. Many of the worst evils in modern forms of competition could be diminished by merely bringing that part of the law which relates to economic problems of modern growth into harmony with that which relates to the old-fashioned and well-matured economic questions relating to common picking and stealing. And somewhat similar remarks apply to the punishments for infringements of the Factory Acts.

But at best the action of the law must be slow, cumbrous, and inelastic, and therefore ineffective. And there are many matters in which public opinion can exercise its influence more quickly and effectively by a direct route, than by the indirect route of first altering the law. For of all the great changes which our own age has seen in the relative proportions of different economic forces, there is none so important as the increase in the area from which public opinion collects itself, and in the force with which it bears directly upon economic issues.

For instance, combinations of labour on the one side, and of employers on the other, are now able to arrange plans of campaign for whole trades, for whole counties, for the whole country, and sometimes even beyond. And partly on account of the magnitude of the interests concerned, partly because trade disputes are being reduced to system, affairs which would be only of local interest are discussed over the whole kingdom.

The many turbulent little quarrels which centred more often about questions of individual temper than of broad policy are now displaced by a few great strikes; as to which public opinion is on the alert; so that a display of temper is a tactical blunder. Each side strives to put itself right with the public, and requires of its leaders above all things that they should persuade the average man that their demands are reasonable, and that the quarrel is caused by the refusal of the other side to accept a reasonable compromise.

This change is increasing the wisdom and the strength of each side; but the employers have always had fairly good means of communication with one another; it is the employed that have gained most from cheap means of communication by press, by railway, and by telegraph, and from improvements in their education and in their incomes, which enable them to make more use of these new and cheaper facilities. And while the employers have always known how to present their case to the public well, and have always had a sympathetic public, the working classes are only now beginning to read newspapers enough to supply an effective national working-class opinion; and they are only now learning how to present their case well, and to hope much from, or care much for, the opinion of those who are neither employers nor of the working classes.

I myself believe that in all this the good largely predominates over the evil. But that is not the question with which I am specially concerned at present. My point is that, in the scientific problem of estimating the forces by which wages are adjusted, a larger place has to be allowed now than formerly to the power of combination, and to the power of public opinion in judging, and criticising, and aiding that combination; and that all these changes tend to strengthen the side of the employés, and to help them to get a substantial though not a great increase of real wages; which they may, if they will, so use as to increase their efficiency, and therefore to increase still further the wages which they are capable of earning, whether acting in combination or not.

§ 19. Thus public opinion has a very responsible task. I have spoken of it as the opinion of the average man; and he is very busy, and has many things to think about. He makes great mistakes; but he learns by all of them. He has often astonished the learned by the amount of ignorance and false reasoning which he can crowd into the discussion of a difficult question; and still more by the way in which he is found at last to have been very much in the right on the main issue. He is getting increased power of forming a good and helpful opinion, and he is being educated in mind and in spirit by forming it, and by giving it effect. But in the task which he is undertaking there are great difficulties ahead.

In an industrial conflict each side cares for the opinion of the public at large, but especially for that of those whose sympathy they are most likely to get: in the late South Wales strike, for instance, the railway companies were specially anxious about the good opinion of the shippers, and the engine-drivers about that of the colliers. And there is some fear that when party discipline becomes better organised, those on either side will again get to care less for any public opinion save that of their own side. And if so, there may be no great tendency towards agreement between the two sides as to what are reasonable demands.

It is true that there is always the action of outside competition tending to visit with penalties either side which makes excessive use of any tactical advantage it may have obtained. As we have just noticed, the shrewdest organisers of a Trust are averse to raising the price of its wares much above the normal or steady competition price. And the first point which courts of Conciliation and Arbitration have to consider is, what are the rates of wages on the one hand and of profits on the other, which are required to call forth normal supplies of labour and capital respectively; and only when that has been done, can an inquiry be properly made as to the shares in which the two should divide between them the piece of good or ill fortune which has come to the trade. Thus the growth of combinations and partial monopolies has in many ways increased, and in no way diminished, the practical importance of the careful study of the influences which the normal forces of competition exert on normal value.

But it must be admitted that the direct force of outside competition in some classes of wages disputes is diminishing; and though its indirect force is being increased by the increased power which modern knowledge gives us of substituting one means of attaining our ends for another, yet on the whole the difficulty of deciding what is a reasonable demand is becoming greater. The principles on which not only the average man, but also an expert court of Conciliation or Arbitration should proceed in forming their judgment, are becoming, in spite of the great increase of knowledge, more and more vague and uncertain in several respects.

And there are signs of a new difficulty. Hitherto the general public has been enlightened, and its interests protected, by the fact that the employers and employed when in conflict have each desired to enlighten the public as to the real questions at issue; and the information given on one side has supplemented and corrected that on the other: they have seldom worked together systematically to sacrifice the interests of the public to their own, by lessening the supply of their services or goods, and thus raising their price artificially. But there are signs of a desire to arrange firm compacts between combinations of employers on the one side and of employés on the other to restrict production. Such compacts may become a grievous danger to the public in those trades in which there is little effective competition from foreign producers: a danger so great that if these compacts cannot be bent by public opinion they may have to be broken up by public force.

It is, therefore, a matter of pressing urgency that public opinion should accustom itself to deal with such questions, and be prepared to throw its weight against such compacts as are injurious to the public weal, that is, against such compacts as are likely to inflict on the public a real loss much greater than the gain to that trade; or in other words, are of such a nature that if their principle were generally adopted in all trades and professions, then all trades and professions would lose as buyers more than they would gain as sellers.

§ 20. To sum up. It seems that one cause of the present strength of Protection in other countries is, that the earlier English economists lessened the force of the valid arguments against it by mixing them up with others which, though valid as regards England, did not apply without great modifications to new countries; but economists of the younger generation, however fervent their devotion to Free Trade, seldom speak of Protection in new countries with the old, unmeasured bitterness. The change of mental attitude towards competition in this aspect is in a great measure accomplished; and similar changes in the attitude of economists to monopolies and combinations are now in progress. It is clear that Combinations and partial Monopolies will play a great part in future economic history; that their effects contain much good as well as much evil, and that to denounce them without discrimination would be to repeat the error which our forefathers made with regard to Protection. If we do not take Time by the forelock, and begin early to consider how their evil effects may be minimised and their possible good developed, we shall miss an opportunity that will never recur; for a later generation will find it more difficult to extricate the good from the evil than those who are contemporary with that great growth of the facilities of communication which are giving to the forces of combination and monopoly a new character, and in some directions a new strength.

So far nearly all the younger economists appear to be agreed. But while some would not be sorry to see small firms displaced by large, large firms by Trusts, and Trusts by Government Departments, others, in whom the Anglo-Saxon spirit is stronger, regard these tendencies with very mixed feelings, and are prepared to exert themselves to the utmost to keep Government management within narrow limits. They are most anxious to preserve the freedom of the individual to try new paths on his own responsibility. They regard this as the vital service which free competition renders to progress, and desire on scientific grounds to disentangle the case for it from the case for such institutions as tend to maintain extreme inequalities of wealth; to which some of them are strongly opposed. In order to preserve what is essential in the benefits of free competition, they are willing to have a great extension of public control over private and semi-public undertakings; but, above all, they look to the extension of the new force of public opinion as a means of eliminating much of the evil effects of competition, while retaining its good effects.

I have spoken of some aspects of competition, but those of which I have said nothing are more numerous, and certainly not less important. I have purposely put aside, as belonging to a different order of inquiry, the moral aspects of competition, and all study of its bearing on those who are least able to help themselves. But I should have liked, if time had sufficed, to compare the tendency towards the formation of vast Trusts with that towards national or even international federation of Trade Unions; and, again, with the growth of the centralised force of the Co-operative Wholesale Society. I should have liked to examine the new forms of indirect competition between industrial groups, each of which is in direct competition with a third one, and so on.

I have, however, taxed your patience too long already, and must ask you to be lenient in your judgment of this imperfect and fragmentary study. I have endeavoured to give some illustrations of the changes which are coming over economic studies. I believe that the great body of modern economists think that the need of analysis and general reasoning in economics is not less than our predecessors supposed, but more. And this is because we think economic problems more difficult than they did. We are recognising more clearly than they did that all economic studies must have reference to the conditions of a particular country and time. Economic movements tend to go faster than ever before, but, as Knies pointed out, they tend also to synchronise; and the economists of our own country have much more to learn now than fifty years ago from the contemporary history of other countries; but in spite of the many great benefits which we are deriving from the increase of our historical knowledge, the present age can rely less than any other on the experience of its predecessors for aid in solving its own problems.

Every year economic problems become more complex; every year the necessity of studying them from many different points of view and in many different connections becomes more urgent. Every year it is more manifest that we need to have more knowledge and to get it soon in order to escape, on the one hand, from the cruelty and waste of irresponsible competition and the licentious use of wealth, and on the other from the tyranny and the spiritual death of an ironbound Socialism.

The following Papers were read :—

1. *Modern Forms of Industrial Combination. By* Professor A. T. HADLEY.

Combinations have two distinct purposes—economy in production or monopoly in sale. The former tends to lower prices; the latter, as a rule, to raise them. The law has therefore favoured the former and discouraged or prohibited the latter. In past times it has been easy to draw this distinction; to-day it is no longer possible, for two reasons: 1. In many lines of industry (*e.g.*, railways) capital is invested on so large a scale that economy practically involves monopoly. 2. In all industries with large fixed capital competition often reduces prices below cost, driving some concerns out of business, and causing fluctuation of prices (*e.g.*, iron trade) and waste of capital. If some of this waste and fluctuation can be avoided by monopoly, it may involve public economy. Modern forms of combination have this double character as monopolies and means of economy.

A mere agreement to maintain rates is often tried, but almost always ineffective. A 'corner,' which attempts to control the sale of the product rather than the means of production (*e.g.*, the metal syndicate of 1887–88), is sometimes temporarily successful, but not permanently so. Of more lasting use have been divisions of traffic between different producers, either a division of the field (gas companies), or an allotment of traffic by percentage, sometimes called a 'pool,' in use among factories, shipping, and railways. The International Steel Rail Combination (England, Belgium, and Germany) was the widest instance. Finally, they may divide, not the traffic, but its proceeds (joint purse agreement), often coming little short of actual consolidation. The Standard Oil Company has made the greatest success in this kind of consolidation. A 'Trust,' as used in America, is simply a means to this end, whose importance has been over-estimated.

The dangers from combination are more obvious than the policy to be adopted. Some advocate direct prohibition; this fails to-day because what is necessary and economical is so intermixed with what is dangerous. Some advocate recognition and supervision by the Government. The danger here, as in most cases of legalised monopoly, is that the protected combinations will not be worked up to the best standard of efficiency. A third policy, advocated by the Socialists, is that the Government itself should own such industries. This solution is liable to the same dangers as the second, and usually in a greater degree. The safest policy would seem to be one of *laissez-faire*, based on somewhat different grounds from those which would have been advanced thirty years ago. We can no longer hold that free competition is an automatic regulator of prices, always tending to put them where they belong, and that combination is economically wrong. But we can maintain that the possibility of competition is the best if not the only available stimulus for high industrial efficiency; that unprotected combinations can succeed only when they forestall such competition by efficiency and low prices on their own part; and that, though the leaders of such combinations have not as yet fully learned this lesson, there is an educational process going on, which radical interference on the part of Government would tend to check, without being able to offer anything equally promising in its place.

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2. *The Ulterior Aims of Co-operators. By* BENJAMIN JONES.

Statistics submitted to the last Annual Co-operative Congress show that in 1889 there were 1,515 co-operative societies with 1,054,996 members, and 13,675,819*l.* of capital. Their sales for the year were 40,225,406*l.*, and their nett profits after paying interest on capital were 3,775,464*l.* The increase in 1889 over the year 1888 was fully ten per cent.

These associations have been gradually developed during the last one hundred years, and there are over thirty societies in existence whose birth dates from fifty up to one hundred and thirteen years ago. But the growth of co-operation has been mostly the result of the last twenty-five years, and the business of one society alone in 1889 was more than double the total trade of all the co-operative societies in 1865.

While the majority of the societies have not yet got beyond the elementary stage of co-operation, which is shopkeeping, large numbers have added productive departments, such as baking, tailoring, dressmaking, and bootmaking. The annual production is estimated to be 3,500,000*l.* Twenty-three societies also work corn mills, with an annual output of over 1,500,000*l.* The oldest existing society was started in 1795, and its first mill cost 2,200*l.* The newest corn mill belonging to co-operators is on the Tyne, and is approaching completion. Its cost will be 100,000*l.*, and it will add about 400,000*l.* a year to the total output of the co-operative mills.

There are two co-operative wholesale societies which supply the retail societies on the same principles as the latter supply their individual members. 1,123 societies have shareholders. Their annual trade is 9,300,000*l.*, and they manufacture boots, woollen cloth, clothing, soap, biscuits, jams, &c., to the value of 370,000*l.* a year.

Thirty-seven societies are engaged in farming operations, and there are seventy-three other societies that are organised specially for various manufacturing operations. Their annual produce is about 700,000*l.*

A very important development of co-operation has been the formation of working-class joint-stock companies in the cotton industry. The oldest existing company was started at Bacup in 1850. Now half the cotton spinning of Oldham and district is done by these companies.

Among the miscellaneous efforts of co-operators are the building of houses for their members, the expenditure of 30,000*l.* a year on education, the granting of 11,000*l.* a year to charitable purposes, and the subscription of 5,000*l.* a year to the Co-operative Union, which is an organisation comprising most of the societies for propagandist, educational, and defensive purposes.

The sense of the injustice of the ordinary industrial and commercial methods is the cause of the inception and growth of co-operation. The leading idea has always been a desire for equity; and they have felt that, just as in political matters, the more democratic the organisation of a government becomes the more the wants of the great masses of the people are considered; so, in the world of labour, democratic organisations would give to the worker that just consideration and treatment which the master-and-man system has failed to supply.

Co-operators fully recognise the benefits of division of labour, and of free exchange of products. But they think that to ensure equitable exchange there must be full knowledge and equal power, or, in their absence, a cultivated self-restraint on the part of the best informed and most powerful. They insist on the necessity for publicity in all essential matters, on the advisability of the one man one vote principle in industry as well as in politics, on the necessity for all men possessing capital, and on the abolition of all monopolies.

They think that co-operation ensures to every willing man an easy means of acquiring capital, and of securing equity in all things; and if co-operators cannot break down monopolies without the aid of the Legislature, they will not fail to seek that aid in the same manner as they have repeatedly done in the past, when otherwise insuperable obstacles required to be removed. Co-operators look upon local and imperial government as links in the chain of a complete system of co-operation, and they are steadily increasing their active share in the task of government. Personally, the writer thinks that there are indications of co-operators taking a rapid step in exerting greater influence on the Legislature, as a means of accelerating the progress of industrial co-operation.

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3. *The Value of Labour in relation to Economic Theory.*[1] *By* JAMES BONAR.

The author, after pointing out that labour is valued by the labourer as the means of living, and by the employer as a means of production, said that the essence of work for wages is that some one other than the labourer owns the

[1] Printed in the *Quarterly Journal of Economics* (Harvard), 1891.

articles made and gets their price, while the labourer gets a stated or stipulated sum for the making of them. The employer may regard labour as a commodity, but it is not so in the same sense as his other means of production. The position of free men is *sui generis*; and the power of a wages-earner to mutiny or desert is the germ of all improvement in his condition. He binds himself to work by a free contract, though, in the lowest forms of work for wages, his real dependence, through ignorance and poverty, makes the freedom merely nominal. Combination gives him a real power of choice, and may even make him stronger than the employer. The wages of salaried managers of a company are to be treated as similar; but wages of management are usually difficult to distinguish from profits. In what way are all such wages related to cost and price? Not as other means of production; for there is no market for labour in the sense in which there is for capital and commodities. The employer values the labourer by his contribution to the product, but what is the relation of the labourer's retribution to his contribution? The theory of a wages fund defined his retribution by a general law, according to which the wages were predetermined by the employer's capital or a stated portion of it. The theory was used too much as a statement of facts instead of tendencies, and it depended on wrong assumptions about the equality of the rate of profits, &c. A more recent theory that wages are determined by the successful or unsuccessful competition of machinery with hand-labour does not explain all the facts. There is a sense in which wages are limited by capital and are advanced out of capital. The burning question is as to the precise extent of the limitation. There is a margin within which wages may vary favourably or unfavourably to the labourer in proportion to his strength through combination or other resources. Even the theory that wages depend on the productiveness of labour cannot ignore this margin. It is difficult in all cases to allocate to the workman and to the co-operating means of production their exact respective shares in the product. Even the theory of Jevons does not escape the difficulty, and President Walker's really inverts the relations of employer and employed. The existence of piecework, the sliding scale, and attempts at profit-sharing are an acknowledgment that wages do not at present vary with productiveness. The notion of final utility is of less use here than elsewhere, because (owing to labourers' combinations and the probability of their increasing strength) wages are determined rather by and for groups than individuals, and labour cannot be used in great and small quantities at the pleasure of the employer. The cost of living, again, will not furnish an adequate theory of wages; and, finally, though labour is part of the employer's cost, neither labour nor any other part of the cost can, strictly speaking, be said to determine the value; it is the anticipated value that makes the cost seem worth incurring. The author's conclusions were that general theory can do no more than lay down certain physical and moral limits within which wages will be fixed. The employer's power to pay 'wages' (as such) is limited by the capital at his disposal for that purpose, and his will to pay them is limited by his calculations of the value of the product. On their part the employed cannot take less than what secures them bare life, and will not take less than what secures them the conventional standard of living, while their power to secure more than this will depend on their general resources as compared with the employer's.

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4. *Progressive Taxation.* *By* C. F. Bastable, *LL.D.*

Growing importance of the question. The older economists (with some exceptions) in favour of proportional taxation. New influences in recent years, viz.: (1) Increased popular power, with tendency to place the burden of taxation on the rich; (2) modern economic theories as to (*a*) capacity of taxpayers, and (*b*) the nature of value and utility. Necessity for distinguishing apparent from real progression. Chief examples of former: (1) Freedom of the minimum of subsistence from taxation; (2) exemptions and abatements in favour of small incomes in order to counterbalance the undue pressure of indirect taxation. Real progression: its forms; usually that of an income or 'property' tax. Principal objections: (1) Arbitrariness; (2) risk of evasion; (3) hindrance to accumulation of wealth; (4) unproductiveness. Argument for progression as realising equality of sacrifice. Vagueness of sacrifice as a measure. Criticism of the argument that the rule of proportional taxation must fall with the 'assurance' theory of the State. Proportional taxation as a working rule of finance. Experience of progression mainly confined to small areas, and therefore (even if favourable) of little service in considering the case of large territories. The social aspect of progressive taxation. Objection to the use of taxation for non-financial aims. Conclusion.

FRIDAY, SEPTEMBER 5.

The following Papers were read:—

1. *The Probable Effects on Wages of a General Reduction in the Hours of Labour. By* Professor J. E. C. Munro.—See Reports, p. 472.

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2. *The Agricultural Changes in England during the Period* 1450–1650. *By* Professor W. J. Ashley.

Recent writers have called attention to the agrarian changes in England in the sixteenth century—changes which may be briefly described as the substitution of pasture, or of a convertible husbandry with a preponderance of pasture, for the tillage of the old common-field system. The object of the present paper will be to determine the methods by which, and the extent to which, the change was effected.

For this purpose it is necessary to distinguish between the various parts of a manor:—

(1) As to the *demesne.* It had long been usual, where the lord was non-resident, to lease the demesne to a *farmer.* [This, as applied to agriculturists, seems to have been the earliest, and for some time the most important use of the term; and it was probably only during the sixteenth century itself that it came to be more generally applied to tenants of all sorts.] Here the lord could not be hindered from taking the land into his own hands, when the lease expired, and devoting it to pasture; or from taking advantage of the increased demand for land for sheep-breeding, to demand a higher rent. So far as the demesne lay in intermixed strips in the common-fields, difficulties might arise owing to the claim of the tenants to commonage on the fallow, though it is improbable that they would receive any support from the law courts; and the withdrawal of such strips from tillage would hasten the break-up of the common-field system as a whole. But it remains to be determined to what extent the demesnes were still composed of such intermixed strips.

(2) As to the lands possessed by *freeholders.* Here again there would probably be no legal obstacles in the way of enclosure; and the effect of such action upon the three-field system would depend on the extent to which free holdings still lay in the common-fields, which has not yet been ascertained.

(3) As to the *common pasture and waste.* Legislation and legal decisions as to the right of approver probably gave the lords, where the pasturage was at all extensive, a tolerably free hand. Where the pasturage was limited the lords could, and frequently did, overstock it with their own sheep. The diminution of common pasture would have an injurious effect upon the common-field tillage, and would lead, in some measure, to its abandonment.

(4) But the chief interest of the subject lies in the *villein, customary, or copyhold tenancies.* In the second half of the period, such enclosures as did occasionally take place would appear not to have involved the dispossession of landholders, and to have been injurious only to the cotters. But there is abundant evidence that great numbers of customary tenants were dispossessed during the first half of the

period, especially in the early years of the sixteenth century. And this brings us to the important point, viz. that the agrarian changes were facilitated by the law of customary tenure; which but slowly recognised, or, at any rate, provided means for enforcing, the right of the customary tenants to undisturbed and hereditary possession. The law as it appears towards the end of the period in Coke is very probably itself the outgrowth of the policy of the government, and of public opinion, in relation to the action of the lords of land, and does not represent the older law. This seems to be shown, among other arguments, by the history of the celebrated clause in the later editions of Littleton, as to the judgment of Chief Justice Brian, and by a comparison with legal doctrine in other countries, *e.g.*, in North Germany, where the conditions were in several respects similar. The views which have of late years been taken of the history of land-tenure in the Middle Ages, have been unduly coloured by the assumption that the manor grew out of a free community, and that the lord's legal rights were all encroachments. It would seem more likely that the legal right of the lord to dispossess his villeins is very ancient; that it was exercised most sparingly for centuries merely because it was rarely profitable; that as soon as it became profitable it was exercised; and that it was not taken away until it had had great practical consequences.

A similar point is illustrated by the development of the law as to *fines* on succession. It is probable also that in many cases the way was prepared for the removal of customary tenants by the substitution of *leases* for copyhold.

The extent of the revolution can only be exactly estimated when due regard has been paid to each of the possible directions in which change could be effected. All that can be here attempted is to take the most important of the innovations—the enclosure of the open arable fields—and discover the area affected. This can be done to some extent upon the evidence of contemporary writers: thus there is a concurrence of authorities that Essex and Kent were pretty completely enclosed (in this sense). But the vague declamations of the pamphleteers of the period need examination, *e.g.*, in the case of Oxfordshire; and even such a fact as the rising in Norfolk does not bear the interpretation which it might seem natural to put upon it. A more satisfactory basis for an estimate is to be found in the information given in the Reports to the Board of Agriculture, in Arthur Young's *Tours*, and in Enclosure Acts, as to the extent to which common-fields still survived in 1750.

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3. *The Element of Chance in Examinations.* *By* Professor F. Y. Edgeworth, *D.C.L.*

This paper is a sequel to the paper on the Statistics of Examinations which was read before the British Association in 1888, and was published in the 'Journal of the Statistical Society' for the same year. In that paper it was shown that the discrepancies between examiners marking the same work are subject to the laws of error which govern the differences between observations relating to the same physical quantity. This theory is now exemplified by a variety of statistics. It is shown that the following questions can be answered with some precision when the requisite data are available: At a given examination how many of the successful candidates are quite safe—in this sense, that the chance is very small (say 1 in 100) that any assigned one of them would have come out unsuccessful if the work had been appraised by a different examiner or set of examiners? Of such displacements, what is the most probable number under given circumstances? The answer to the first question varies from a third to two-thirds of the successful candidates. In answer to the second question it is found that the number most likely to be displaced by a change in the *personnel* of the examiners is sometimes a seventh part of the number of the successful, sometimes less. It is shown that the method of eliminating chance by manipulating the marks after they have left the examiner's hands is often precarious and ineffective. Other methods of alleviating the evil are considered.

SATURDAY, SEPTEMBER 6.

The following Papers were read:—

1. *The Policy of exercising a Discrimination between the Deserving and Undeserving in the giving of Public Poor Relief. By* JOHN KING.

The writer of the paper suggested that, had time permitted, the *policy* of exercising such a discrimination might have been considered in connection with the *possibility* of doing so, with advantage.

Because, if a correct discrimination be impossible in practice, it would clearly be impolitic to attempt to discriminate at all. For present purposes it will not be assumed that it is impossible, leaving the policy of discriminating alone to be considered.

The subject could not be dealt with satisfactorily in the abstract; experience would have to be utilised.

The writer proceeded to define 'deserving' and 'undeserving' poor; and assumed it would be granted that pauperism was a social evil, which it was necessary to limit by measures of a repressive tendency; that the claims of the destitute were to be considered in connection with the public interests. Among civilised nations it was an admitted principle that no citizen should perish from want; but it was the duty of the State so to administer relief as to encourage industry and provident habits; and the converse. The proper measure of public relief should be restricted to affording the bare necessities of life; and the reason was not far to seek, in the fact that such were all the poor labourer could procure for himself and family by work. Fairness to him, therefore, directed that the position of the indigent, maintained at the public expense, should, at least, be no better. In the pauper's own interest it should be no better; and the public weal demanded that also.

These axioms were the result of experience and thought, and were taught by history. The effects of giving almost unrestricted relief were disastrous to Athens and Rome. In the former an impoverished State was attended with loss of individual liberty; whilst in the latter the physical and moral attributes were in a great measure sacrificed to the custom of State relief, and induced the decline of the world's dictator. But our own country furnished sufficient illustration, which would receive attention.

The origin of the Poor Law was then described, and the cost of the system during the past year. In a matter of necessity, however, cost was immaterial. It was not at all certain that the money spent in relief was all expended in the relief of destitution; if it were, then the social system must be very imperfect. The legislature of the period of Elizabeth had two main objects in view—to relieve the aged and infirm, and to set to work the able-bodied. But gradually a departure from this wise legislation was taken, and the relief became aids to poverty, granted almost without test, and, at one time, without care or discrimination of any noteworthy character.

Between the years 1720 and 1795, grants to the poor greatly increased, and, as a consequence, pauperism. To so great an extent was this carried on, that in rural districts the greater portion of the poor classes received public relief. All inducement to industry, morality, and the other social virtues was taken away; poverty and intemperance increased, until, finally, the matter became so serious as to threaten national disaster. Population increased to an abnormal extent, and illegitimacy became rampant. By the Act 36 Geo. II. cap. 10, it may be said pauperism was encouraged, and working under it, magistrates gave effect to the legislative spirit, and in very many instances issued orders to the local authorities to discriminate between the deserving and the undeserving. The mischief of this was apparent; the poor themselves not only obtained relief up to the measure of their necessities, but probably something over; whilst the favourable opinion of the overseer as to some of them resulted in their procuring still greater liberality, to their own hurt and the loss of the ratepayers, who thus became the subjects of unfair treatment.

Up to this point there was little room for the exercise of a discrimination appertaining to a semblance of check or repression. Injustice reached the culminating point: and if the experience of that day was to be made use of, the error under any such or like circumstances would never be repeated. The unsound policy was clearly seen, and the only excuse for it was the exigencies of a political party.

Errors were multiplied with the miseries accompanying them. The State was decidedly sick, and at last the Royal Commission of 1834 was appointed to inquire into the evils of Poor Law administration, and point out the necessary remedies.

Their report was quoted, and the author of the paper gave an epitome of its contents, and also of the two principal Orders for the prohibition and regulation of relief. In these the directions were so large and comprehensive as to those who were to be relieved, that very little room was left for the exercise of any general discrimination between classes; whilst the orders were entirely silent on the matter of discerning between the good and the bad.

Acts of Parliament, orders, rules, and regulations appear to have been issued utterly regardless of the distinction of character; and this avoidance of the matter was no doubt the direct result of the Commission, which clearly adverted to the evils which had theretofore to some extent resulted from the licence to discriminate.

Such evidence as that produced to the Commissioners ought to be received as a warning, and their conclusions and advice received with the utmost respect. The exercise of a discrimination upon the basis of character at the present time had the tendency to destroy great principles, found to be necessary for the safe administration of relief, and consequently to obliterate the proper lines of action.

The necessities of the applicant alone ought to be the ground of granting relief.

Indoor relief, being the kind least likely to be abused, required to be surrounded by no very stringent safeguards. But the principles governing the grant of out-relief were in a great measure identical with those practised with regard to the latter. The condition of the workhouse indigent, so far as it might be regarded from the cost point of view, ought not to be better than that of the poor labourer. But even workhouse cleanliness, wholesome food, given at regular intervals, good shelter, and necessary warmth were comforts such as but few of the poorest class could command.

A summary of the contents of the paper would lead to the conclusion, that upon the question whether an indigent should or should not receive assistance from the public funds, there ought to be no exercise of a discrimination between the good and bad. But when the nature of the relief to be given came to be considered, a minor discrimination might be judiciously exercised.

In the workhouse, a safe and sound discrimination might be attempted. There were to be found there persons whose condition had not been induced by any errors of their own, and a sub-classification might be made, having in view the placing together of such persons, when such privileges might be accorded them as to render their position less irksome; not forgetting, however, the necessity still to make it an undesirable place of abode.

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2. *Exhibition of Maps illustrating the Statistics of Pauperism. By* Dr. RHODES.

MONDAY, SEPTEMBER 8.

The following Papers were read:—

1. *Joint Discussion with Section E (Geography) on Lands still available for European Settlement.*

2. *Some recent Changes in the Conditions governing the London Money Market.* *By* WYNNARD HOOPER.

Bagehot's 'Lombard Street.' His remarks on the 'natural system' of banking, many banks each keeping its own reserve. The system that has grown up in London is one in which a single bank keeps the *whole* reserve of the country. The system cannot be altered. Bagehot showed how it could be worked safely. He practically established a 'canon of criticism' in relation to the management of the Bank of England's reserve. The difficulties of the bank have increased since he wrote 'Lombard Street.' The volume of business is larger, and the liabilities of London and the whole country are much larger, but the reserve held against them is only slightly larger than was the case twenty years ago. Improved steam communication and the use of telegraphic transfers have made it possible to work with a *relatively* smaller reserve, by enabling the four great centres of business to support one another.

The fabric of credit as indicated by the London Bankers' Clearing Returns has increased from 3,914 millions sterling in 1870 to 7,618 millions sterling in 1889, or by about 95 per cent. This is due mostly to the growth of internal trade. It implies an increased use of cheques, including 'international cheques,' or telegraphic transfers, and has been accompanied by a diminished use of bills of exchange. Cheques of very small amounts are now common, which was not so even ten years ago. Most people now 'keep a banker.'

The deposits of banks have enormously increased. Those of the fourteen principal London banks have risen from 103 millions in 1870 to 178 millions in 1889. Other banks' deposits have also increased, and a larger proportion of the deposits are kept in London to be lent.

On the other hand, the reserve of the Bank of England is, on the average, very little larger than it was during 1870-79. Of course, the reserve is now 'more efficient' than it used to be, for reasons already given, but nevertheless it is too small. The Bank's power over the market is not great enough to enable it to keep a proper reserve without making special efforts.

What should the reserve be? It need not, at any rate, be increased in proportion to the whole increase in the banking liabilities of the country. But some increase should have taken place on this score, and, further, the Bank cannot disregard the fact that it is the only free 'international bullion store.' The Banks of France and Germany prevent withdrawals of gold from their coffers. The Bank of England cannot do that.

The remedy. Mr. R. H. Inglis Palgrave urges that the responsibility for the reserve must be shared by the great banks whose operations govern the discount rate; but they will not accept this responsibility, and the Bank must therefore use its resources, which are very great, more freely, and obtain more control over the market. This it has been to some extent doing during the last few months. It might offer interest on deposits and do more discount business, and thus deprive the other banks of part of their power over the market.

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3. *The pure Theory of Distribution.* *By* ARTHUR BERRY, *M.A.*

The paper attempts to give the outlines of a theory of distribution based on consideration of the 'marginal productivity' of each factor of production. Von Thünen and others have shown that the wages of the last labourer in any business are measured by the extra produce due to his labour. This is not true if the increase of produce causes a sensible lowering of price, since this affects the whole produce and not merely the extra produce. A new equation, involving change of price, is then necessary. Von Thünen's equation holds if the produce of each business is a small fraction of the total amount of the commodity produced. This assumption is here made. The same considerations apply to the other factors of production. It is assumed also, for simplicity, that a small increase in a business causes no increase of work to the entrepreneur himself.

The whole production of a community is regarded as being carried on by a number of entrepreneurs hiring land, labour, and capital, the two former being of several different qualities. For each entrepreneur there is a production function $f(g_1, g_2, g_3 \ldots l_1, l_2, l_3 \ldots c)$ expressing the amount of commodity produced annually by the use of $g_1, g_2, g_3 \ldots$ yards of lands of the 1st, 2nd, 3rd ... qualities, $l_1, l_2, l_3 \ldots$ hours of labour of the 1st, 2nd, 3rd ... qualities, and c pounds of capital. The form of f depends on the entrepreneur's skill, 'opportunity,' &c., and is regarded as known for each entrepreneur. Then if ρ_k be the rent per annum per yard of land of the k-th quality, w_j the wages per hour of labour of the j-th quality, i the interest per annum per pound, all measured in money; and $p_1, p_2 \ldots$ the prices of the commodities produced by the 1st, 2nd, 3rd ... entrepreneurs, the equations of marginal productivity are—

$$p_1\frac{df_1}{dg_k}=\rho_k \qquad p_1\frac{df_1}{dl_j}=w_j \qquad p_1\frac{df_1}{dc}=i \text{ for all values of } j,\ k.$$

$$p_2\frac{df_2}{dg_k}=\rho_k \qquad p_2\frac{df_2}{dl_j}=w_j \qquad p_2\frac{df_2}{dc}=i,$$

and so on for each entrepreneur.

For each commodity there is a demand equation of the form $p=\phi(f+f'+\ldots)$, where $f, f', f'' \ldots$ are the amounts produced by the several entrepreneurs who produce the same commodity.

The conditions which remain to be expressed are that the whole available amounts of land and labour of each quality and of capital are used. The last gives $\Sigma c = C$, where Σ denotes summation for all entrepreneurs and C the total amount of capital. We may roughly assume the amount of land of any quality available at any time as known, or more accurately, take into account the quantity γ_k used for private houses, &c., for which there is a demand equation $\rho_k=\psi(\gamma_k)$; and then $\Sigma g_k+\gamma_k=G_k$, where G_k denotes the existing amount of land of the k-th quality. Similarly $w_j=\frac{d\chi(\Sigma l_j)}{dl_j}$, where χ is an 'average' disutility function for labourers of the j-th quality. We now have as many equations as unknowns, and the latter are therefore determinate. The rate of growth of population and rate of accumulation of capital do not enter into the equations. There is no more justification for assuming wages to be measured by the produce of a labourer working on the margin *without capital* than for assuming interest to be measured by the produce of an amount of capital *without labour*.

If land, labour, and capital are perfectly mobile (*i.e.*, can be transferred freely from entrepreneur to entrepreneur), then ρ_k, w_j, i are the rates of payment of all the land labour and capital, and not merely of the marginal doses. The entrepreneur's share is then the surplus $pf-\Sigma g\rho-\Sigma lw-ic$. If in any business this surplus generally exceeds the surplus obtained in another business by entrepreneurs of equal skill, &c., entrepreneurs tend to pass from the second business to the first and to reduce profits in it by lowering prices.

If capital is 'invested,' interest on it is not necessarily the same as that on the marginal dose, and the capitalist's share is in general merged in that of landlord or entrepreneur, and economically undistinguishable.

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4. *A Theory of the Consumption of Wealth.* *By* Professor P. GEDDES.

The importance of the study of consumption has always been recognised by the biologist and anthropologist, the historian and moralist, yet less so by the economist, whose attention at the beginning of the industrial age was naturally awakened by the rapid transformations of the processes of production and distribution, and has since been almost restricted to the elaboration of the economic theory of these phenomena alone. The theory of consumption is thus not only needed for the sake of economic science itself, but would lead to its direct and profitable connection with the study of the other sciences, physical and biological on the one hand, historical and ethical upon the other.

A historic survey is first necessary, dealing with consumption in early and simple civilisations and in barbarism, and then, following the main line of Western civilisation, *e.g.*, interpreting the rise of Greek civilisation to the age of Pericles, its private simplicity and public magnificence (one-third revenue spent on public buildings). The rise of Roman luxury and subsequent exaggeration of this (as in bath and dwelling, in feast or drama) is associated with corresponding progress and decadence, private magnificence and public poverty, naturally culminating in private orgies and public ruin. The historic recurrences of the same evolution may be well illustrated in France, *e.g.*, the periods of Henri IV., Louis XIV., and Louis XV., or the history of the Second Empire. This decay of art and luxury explains the recurrence of sumptuary laws of the Spartan or Puritan criticism of art as efforts after simplification and purification of life by material or moral compulsion towards asceticism.

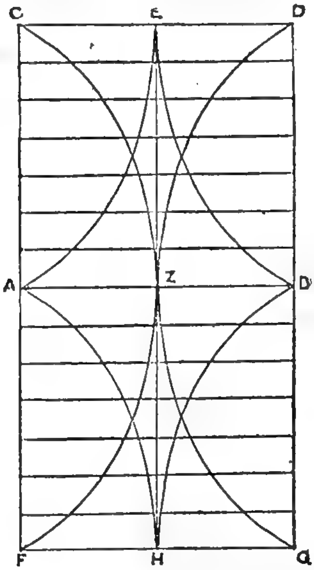
These results of different forms of consumption may be viewed, not only in societies, but in individual detail. A demand for commodities being a command of labour (see Carlyle's well-known passage on the possessor of a sixpence as to

FIG. 1.

Self-regarding.	Species-regarding.
	Species
	Nation
	City
	Assoc.ⁿ
	Family
	Sex
Individual	
-Indiv (Excess)	
	- Sex
	- Family
	- Assoc.ⁿ
	- City
	- Nation
	- Species

FIG. 2.

Self-regarding. Species-regarding.



that extent sovereign over all men), this determines (*a*) the *function* of the consumer, (*b*) the *environment* of the consumer, and so ultimately the duration and the quality of the life of both. Hence the pressing necessity of the theory of consumption to social improvement, and the necessity of co-operation between the economist and the moralist for the criticism and counsel of the consumer.

The different types of consumption, *i.e.*, the 'standards of comfort' which become broadly fixed in each age and country are capable of more precise classification in *grades* and *degrades* above and below the (physiological) necessaries of life. The central question of practical economics may now be stated as that of adjusting these standards of comfort towards the evolution of the species, the society, and the individual. The co-operation of the cultivators of the allied sciences is thus required; and the more familiar problems of what and how to produce, and of how to distribute, are thus also prepared for solution upon a less uncertain basis.

Returning to the processes of consumption, we see, as fundamental, that of food, and next of the individual necessaries of clothing, shelter, &c., with all their associated rise of quantity and quality. Above this comes the consumption for maintenance of the other sex and for that of the family; next arises the consumption of the wider associations arising beyond the family, of which there are many levels—civic, national, and universal. Civilisations and individuals thus first differ in the different proportions of consumption upon each plane.

To each of these planes of legitimate consumption there is, however, to be observed a corresponding negative plane. Thus to the normal or ideal scale of expenditure on individual maintenance we must contrast that on intemperance; to that on family, that on vice; while to those of social well-being there are a no less distinct series of contrasts, widening in their social destructiveness as we descend.

The diagram must not be left blank, however, as in fig. 1, but becomes capable of recording and contrasting the average type or tendency of consumption for any given period or person. Thus A B E may denote the consumption of a non-ascetic society or individual, which leaves only to higher planes what is not required—*i.e.*, consumable on the lower—and C D Z the ideal of the ascetic, who limits every expenditure upon the lower planes in order to spend more upon the higher. Between these two there are, of course, innumerable gradations—Hellenic, Hebraic, Roman, Florentine, in fact, any and every society or individual having its characteristic curve at any given time. But it is each of these states of consumption that determines the nature of production; hence our 'National Œkonomie' (or our contemporary economic theory, which is only a phase of national economy, and has, of course, no permanence) requires a preliminary comprehension of the state and ideals of consumption at the time under consideration. Here, then, also arises the connection of economics with morals, since each ascending plane of consumption is more species-regarding—*i.e.*, more altruistic, more moral—than the one below it. The scheme of classification, founded as it is on the stages of biological evolution, has similar parallels to the stages of psychological evolution, which necessarily correspond, and thus a regular and detailed parallelism of interpretation for any historic fact or social process becomes possible. The aspects of this, biological or psychological, economic and ethical, may thus be kept as clearly apart as the respective specialists could desire, yet may also be superposed or compared at will. The evolution of the animal through the lower stages, and of man through the whole, is the biologist's aspect of the subject; the corresponding evolution of mind the psychologist's; the corresponding concrete social processes are the phenomena observed by the economist; while the subjective aspect of these is criticised by the ethicist. The synthesis of these four aspects is, in fact, the ideal of the science of sociology.

It is only necessary briefly here to note the corresponding negative possibilities of evolution in which the same four aspects become manifest.

The sociological analysis and synthesis here sketched out may now pass from the abstract field to the concrete phenomena, with which the inquiry started, for we see that what the anthropologist and the archæologist, the art critic and the historian (who supply the materials to the four preceding schools of abstract study), are respectively occupied with is, in every case, a study of actual social life and its results upon all four planes, with their ascending and descending stages. In short, within the diagrammatic outlines of the preceding classification may now be reinterpreted alike our facts of ancient or modern history, or the details of our own personal expenditure, and this to their remotest bearings, economic or ethical. We have, in fact, a common denominator by help of which to re-read at will Darwin or Tylor, Roscher or Gibbon, Lepsius or Ruskin—one might add even Zola or Dante.

A base of intercommunication and co-operation between all these abstract and concrete specialists, and this especially as concerns the economist, is thus practicable. The possibility of their co-operation in the criticism of actual life, and in the task of social amelioration, also follows.

TUESDAY, SEPTEMBER 9.

The following Papers and Reports were read:—

1. *The Factories and Workshops Acts—Past and Present.*[1] *By* G. H. L. Rickards.

The author gave a brief summary of the various Factory Acts passed between 1802 and 1889. The more important points in each Act were stated, so that those unacquainted with factory legislation might be able to appreciate the course adopted by the Legislature in promoting the safety, comfort, and improved condition of the industrial classes in this country, as shown by the gradual and careful manner in which the various Acts have been introduced.

The very important Act of 1878 was carefully considered, with reference to 'domestic workshops,' which then formed a new feature of the legislation on this subject. Some remarks followed as to further legislation in that direction. Evidence of the improvement in the physical condition of the factory operatives from personal medical experience was also adduced.

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2. *Modern Changes in the Mobility of Labour.* *By* H. Llewellyn Smith.

The author proposed to discuss the effects on mobility of labour of the introduction of machinery and the tendency to production on a large scale. He treated mobility chiefly from the point of view of free change of occupation rather than of place.

Mobility is not the same as movement, nor is the one measured by the other. We may have high mobility and little movement, and the reverse. Many modern changes tend to increase mobility at the expense of movement. He drew examples from the case of the old nomadic hand-combers, the influx to the towns and the disturbance of labour caused by the Lancashire cotton famine. So in the case of mobility from trade to trade, in normal times there may be in practice no interchange of labour, yet mobility may be almost perfect, except for a slight initial friction. By mobility is meant the free economic choice of employment, either by change of occupation or place. It is measured by the extent to which a set of workers engaged in a particular process, or in making a particular article, would or would not suffer economically by a change in the demand for that process or that article. There is besides 'initial mobility' to be considered, *i.e.*, the free effective choice of occupation at the outset. This is affected by localisation of industries, and the tendency to heredity, which again is strongest in domestic trades and weakest in factories. Excessive localisation of industries is in many districts giving way to local diversification.

Labour may be specialised in two ways—(1) with regard to a particular process, (2) with regard to a particular product, *e.g.*, the modern 'engineer' and the old bootmaker. Thus we have to consider mobility both as (*a*) between different processes of the same manufacture, and (*b*) between corresponding processes in different manufactures. There are then two possible degrees of freedom, and the general effect of machinery is to close the channels (*a*), and open up channels (*b*).

As an example of modern changes, he took the change from the old hand-combers, with their specialised skill, to the modern combing-mill.

(*a*) The makers of the combing machines. Here there are two classes of workers, specialised as to process, but independent of the product.

(β) The workers of the machines. The motive-power department is completely unspecialised so far as the product is concerned. He discussed how far the process of minding the combing machines is specialised.

Examples were drawn from other kinds of machinery, and the power of inter-

[1] Published *in extenso* in *Hygiene*, December 1890.

change among the various textile trades was discussed, especially with regard to the 'initial friction' and the question whether interchange is becoming easier.

He gave a similar analysis of a merchant's business. Business power is rare, but to a very large extent unspecialised with regard to a particular business.

So in many trades which have been taken over by machinery, less mere manual dexterity but more judgment and responsibility are wanted. These are rare qualities but not specialised. Hence their possessor is 'mobile.'

General result. Modern changes tend to divide up a process of manufacture into a number of detail processes of which one man performs only one, but the various members of the group of workers producing a particular article become less and less specialised with regard to that article, and their range of mobility, which is narrowed as regards power of interchange among themselves, is widened as regards power of interchange with workers engaged in corresponding processes of other trades. Machinery often tends to facilitate this interchange by transforming different manufactures into different groupings of nearly identical detail process.

Hence while dividing up employments on the one hand machinery reintegrates them on fresh lines. Thus the boundaries of trades and industries are shifting and industries regrouping themselves. Effect on apprenticeship and trade customs.

The paper touched slightly on the simultaneous tendency to shorten the time necessary to learn a particular detail process, and so to increase the ease (though not always the practical opportunity) of interchange among different processes of the same trade.

The paper with additions and appendices has been published as a monograph by the Toynbee Trustees (London: Frowde & Co. 1*s.* 6*d.*).

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3. *Report of the Committee on the Teaching of Science in Elementary Schools.*—See Reports, p. 489.

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4. *Report of the Committee on the Standard of Value.*
See Reports, p. 485.

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5. *Report of the Committee on the Statistics of the Use of the Precious Metals.*—See Reports, p. 498.

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6. *On the Ideal Aim of the Economist.*
By Mrs. VICTORIA C. WOODHULL MARTIN.

WEDNESDAY, SEPTEMBER 10.

The following Papers were read:—

1. *On the Drawbacks of Modern Economic Progress. By* E. L. K. GONNER.

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2. *On some Typical Economic Fallacies made by Social Reformers.*
By L. L. PRICE, *M.A.*

The paper was devoted to the examination of three characteristic errors of social reformers. Bagehot, in his 'Physics and Politics,' had ascribed the success of Englishmen to the possession of the quality of 'animated moderation;' and at the present time, while there was no doubt that the question of social reform was in a state of animation, it might be doubted whether it was characterised by 'animated moderation.' Englishmen were sometimes reproached for being illogical, but this apparent want of logic was really another aspect of the quality of animated moderation. Bagehot's language was not very precise, but it was suggestive, and the lack of the quality of animated moderation was illustrated by three tendencies which were found in many different quarters.

In the first place, there was the failure to recognise the difference between theory and practice. This was illustrated by the use made of the conception of the 'unearned increment.' In the theory of rent there was a clear and definite distinction between what was earned and what was unearned, but this distinction was obscure and ill-defined in practice; and so far as our conclusions rested on the nicety of the distinction they were inapplicable to practice. The principle of 'betterment' formed in some respects an exception, for it implied a definiteness which was actually found in some cases, and it did not contemplate the possibility of an unearned decrement. The nicety of the distinction on which the conception of the 'unearned increment' was based was realised more vividly when we considered the extension of it to other forms of wealth, which was made in General Walker's theory of business profits.

In the second place, the use of the terms 'socialism' and 'socialistic' might be considered. Mr. G. B. Shaw's paper at the Bath Meeting and Mr. Sidney Webb's book on 'Socialism in England' illustrated a vague and unsatisfactory use of the terms, for the question was essentially one of degree. Neither the sphere of the action of the State, nor the sphere of the freedom of the individual, was conceived by any but the most extreme writers or thinkers to be respectively so comprehensive and so exclusive as to embrace for itself the whole of life and action and to leave no room for the other; and a difference of degree was as important as a difference of kind in the matter of socialism and individualism. The term should therefore be followed by an explanatory clause to show the sense in which it was used, and this was rarely done.

In the third and last place, social reformers were apt to regard their own pet scheme as the one panacea, and to refuse to allow a place in the society of the future to the contemporaneous adoption of other schemes. This was a failing characteristic of some co-operators, who were also liable to exhibit the lack of discrimination considered before. And it was also found in some passages of so fair and impartial an advocate of profit-sharing as Mr. N. P. Gilman. The society of the future would, however, like the society of the past, in all probability be characterised by diversity and not by uniformity.

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3. *The Use of Estimates of Aggregate Capital and Income as Measures of the Economic Welfare of Nations.* *By* Edwin Cannan, *M.A.*

If the wealth of a nation consists of the sum of the wealth of all its individual members, to compare the wealth of different nations we have only to add up the wealth of the individuals of whom each nation consists. But is this wealth which is to be added the individuals' capitals or their incomes? It is usually considered to be their capitals, but it is much more reasonable to consider it their incomes. Some of the objections to taking incomes, and not capitals, are founded on a misleading conception of income, and others on a false analogy from the case of a single individual. Nations being of very different magnitude, aggregate income tells little till it is divided by population. The result of the division is a fiction called average income, which takes no account of distribution. But common sense teaches that very unequal distribution is uneconomic because it is ill-proportioned to needs. This might have been set down as 'mere sentiment' till the introduction of the Jevonian theory of value; but the decreasing utility of additional quantities of any commodity to an individual, which serves as the basis of that theory, also explains why inequality of income, or, strictly speaking, of expenditure, diminishes the utility of a given aggregate income. The fact that the distribution of income, as well as its amount, affects the economic welfare of a nation is fatal to the use of statistics of income, however perfect, as exact measures of the economic welfare of different nations.

SECTION G.—MECHANICAL SCIENCE.

PRESIDENT OF THE SECTION—Captain NOBLE, C.B., F.R.S., F.R.A.S., F.C.S., M.Inst.C.E.

THURSDAY, SEPTEMBER 4.

The PRESIDENT delivered the following Address:—

IN taking over the Chair of this Section from my distinguished predecessor, I cannot but feel myself to some extent an intruder into the domain of mechanical science, and I am conscious that the office which I have the honour to hold would have been more worthily filled by one of the great mechanicians who have won for the town in which we hold our meeting so widespread a reputation.

I can truly say the claims on my time are so considerable that I should not have ventured to appear before you in the character of President of this Section, had it not been for my desire to afford what little support might be in my power to my friend the President of the British Association, with whom for so long a period I have been associated by so many ties.

I believe I should have consulted best both my own feelings and your patience by merely opening the Section in a formal manner, and proceeding at once to the business of the meeting. One of my predecessors, however, has pointed out that Sir F. Bramwell, whose authority is too great to be disputed, has ruled that to depart from the time-honoured practice of an address is an act of disrespect to the Section—a ruling which has, without cavil, been accepted.

I therefore propose to direct your attention, by a few brief remarks, to that branch of mechanical science with which I am best acquainted. I shall endeavour to show the great indebtedness of the naval and military services to mechanical science during the period with which I have been more or less connected with them, and the complete revolution which has in consequence resulted in every department and in every detail.

But before commencing with my special subject, it is impossible that I should pass over in silence the great work which has excited so much interest in the engineering world, and which, since we last met, has, with formalities worthy of the occasion, been opened by H.R.H. the Prince of Wales.

It is in no way detracting from the merit of the distinguished engineers who have with so much boldness in design, with such an infinity of care in execution, with so much foresight in every detail, given to the country this great monument of skill, if I venture to point out that, without the great advance of mechanical and metallurgical science during the present generation, and the co-operation of a host of workers, a creation like that of the Forth Bridge would have been an impossibility.

The bridge has been so frequently and so fully described, that it is unnecessary in this address for me to do more than draw your attention to some of its main features.

The bridge, with its approach-viaducts, has a total length of 8,296 ft., or nearly a mile and six-tenths; and this length comprises two spans of 1,710 ft., two of 680½ ft., fifteen of 160 ft., four of 57 ft., and three of 25 ft.

The deepest foundation is 90 ft. below high-water mark, and the extreme height of the central position of the cantilever is 361 ft. above the same datum, making the extreme total height of the bridge 451 ft.

The actual minimum headway in the channels below the centre of the main spans at high-water spring tides is a little over 150 ft., and the rail level is about 6 ft. higher.

The weight of steel, nearly all riveted work, is 54,076 tons, and the amount of masonry and concrete 4,057,555 cubic feet.

It is difficult, even for experts, fully to appreciate the stupendous amount of work indicated by these figures. During the Paris Exhibition the Eiffel Tower justly excited considerable admiration, and brought its designer into much repute; but that great work sinks altogether into insignificance when compared with the Forth Bridge.

Conceive, as I have heard described, the Eiffel Tower built, not vertically, but horizontally; conceive it further built without support, and at a giddy height over an arm of the sea. Such a work would do little more than reach half across one of the main spans of this great bridge.

Those only who have had work of a similar nature can fully appreciate the innumerable experiments that must have been made, and the calculations that must have been gone through, to secure the maximum attainable rigidity both with respect to the strains induced vertically by the railway traffic and its own weight, and horizontally by the force of gales.

The anxiety as to the security of the erection might well daunt the most skilful engineer. We are told that, apart from the permanent work, many hundreds of tons of weight in the shape of cranes, temporary girders, winches, steam boilers, rivet furnaces, and riveting machines, miles of steel-wire rope, and acres of timber staging were suspended from the cantilevers. A heavy shower of rain would in a few minutes give an additional weight of about 100 tons; and in their unfinished state, while approaching completion, the force of any gale had to be endured.

I trust that as the Forth Bridge has been a great engineering, it may likewise prove a financial success, and I feel sure that all who hear me are rejoiced that it has pleased Her Majesty to confer the distinguished honours she has awarded to Sir John Fowler and Sir B. Baker—honours, I may add, that have rarely been more worthily bestowed.

Let me turn now to the subject on which I propose to address you; and I shall first advert to the change which within my own recollection has taken place in that service which has been the pride and glory of the country in time past, and on which we must rely in the future as our first and principal means at once of defence and attack.

To give even an idea of the revolution which our navy has undergone, I must refer in the first instance to the navy of the past. I must refer to those vessels which in the hands of our great naval commanders won for England victories which left her at the close of the great wars supreme upon the sea.

A 'first-rate' of those days (I will take the *Victory* as a type) was a three-decker 186 feet in length, 52 feet in breadth, with a displacement of 3,500 tons, and she carried an armament of 102 guns, consisting of thirty 42 and 32-pounders, thirty 24-pounders, forty 12-pounders, and two 68-pounder carronades (the heaviest of her guns was a 42-pounder), and she had a complement of nearly 900 men. When we look at the wonderful mechanism connected with the armaments of the fighting-ships of the present day, it is difficult to conceive how such feats were accomplished with such rude weapons.

With the exception of a few small brass guns, the guns were mere blocks of cast iron, the sole machining to which they were subjected consisting in the formation of the bore and the drilling of the vent.

A large proportion of nearly every armament consisted of carronades—a piece which was in those days in great favour. They threw a shot of large diameter from a light gun with a low charge, and their popularity was chiefly due to the rapidity with which they could be worked. The great object of every English commander was, if it were possible, to bring his ship alongside that of the enemy;

and under these circumstances the low velocity given by the carronades became of comparatively small moment, while the ease of working and the large diameter of the shot were factors of the first importance.

The carriages on which the rude weapons I have described were placed were themselves, if possible, even more rude. They were of wood, and consisted of two cheeks with recesses for the trunnions which were secured by cap squares, the cheeks being connected by transoms and the whole carried by trucks. The gun was attached to the vessel's side, and the recoil controlled by breeching. The elevation was fixed by quoins which rested on a quoin bed, and handspikes were used either for elevating or for training.

It is obvious that to work smartly so rude a machine a very strong gun's crew was required. Indeed, the gun and its carriage were literally surrounded by its crew, and I may refer those who desire to acquaint themselves with the general arrangements of what was once the most perfect fighting-machine of the first navy in the world, to the frontispiece of a book now nearly forgotten—I mean Sir Howard Douglas's 'Naval Gunnery.'

The mechanical appliances on board these famed war-vessels of the past were of the simplest possible form, and such as admitted of rapid renewal or repair. There was no source of power except manual labour; but, when handled with the unrivalled skill of British seamen, the handiness of these vessels and the precision with which they were manœuvred was a source of never-ending admiration.

Those who have seen, as I have done, a fleet like the Mediterranean squadron enter a harbour such as Malta under full sail, and have noted the precision with which each floating castle moved to her appointed place, the rapidity with which her canvas was stowed, have seen a sight which I consider as the most striking I have witnessed, and infinitely more imposing than that presented under like circumstances by modern vessels, any one of which could in a few minutes blow out of the water half-a-dozen such men-of-war as I have been just describing.

I must not, however, omit to mention two advantages possessed by the old type of war-vessels, which, if we could reproduce them, would greatly please modern economists. I mean, their comparatively small cost, and the length of time the vessels remained fit for service.

When the *Victory* fought the battle of Trafalgar she had been afloat for forty years, and her total cost, complete with her armament and all stores, was probably considerably under 100,000*l.* The cost of a first-rate of the present day, similarly complete, would be nearly ten times as great.

The most improved battle-ships of the period just anterior to the Crimean war differed from the type I have just described, mainly by the addition of steam power, and for the construction of these engines the country was indebted to the great pioneers of Marine Engineering, such as J. Penn & Sons, Maudslay, Sons, Field, Ravenhill, Miller, & Co., Rennie Bros., &c., not forgetting Messrs. Humphreys & Tennant, whose reputation and achievements now are even more brilliant than in these earlier days.

Taking the *Duke of Wellington*, completed in 1853, as the type of a first-rate just before the Crimean war, her length was 240 feet, her breadth 60 feet, her displacement 5,830 tons, her indicated horse-power 1,999, and her speed on the measured mile 9·89 knots. Her armament consisted of 131 guns, of which thirty-six 8-inch and 32-pounders were mounted on the lower deck, a similar number on the middle deck, thirty-eight 32-pounders on the main deck, and twenty short 32-pounders and one 68-pounder pivot gun on the upper deck.

Taking the *Cæsar* and the *Hogue* as types of second- and third-rate line-of-battle-ships, the former, which had nearly the displacement of the *Victory*, had a length of 207 feet, a breadth of 56 feet, and a mean draught of 21. She had 1,420 indicated horse-power, and her speed on the measured mile was 10·3 knots. Her armament consisted of twenty-eight 8-inch guns and sixty-two 32-pounders, carried on her lower, main, and upper decks. The *Hogue* had a length of 184 feet, a breadth of 48 feet 4 inches, a mean draught of 22 feet 6 inches; she had 797 indicated horse-power, and a speed of $8\frac{1}{3}$ knots. Her armament consisted of two 68-pounders of 95 cwt., four 10-inch guns, twenty-six 8-inch guns, and twenty-eight 32-pounders of 56 cwt.—sixty guns in all.

Vessels of lower rates (I refer to the screw steam frigates of the period just anterior to the Crimean war) were both in construction and armament so closely analogous to the line-of-battle-ships that I will not fatigue you by describing them, and will only allude to one other class, that of the paddle-wheel steam frigate, of which I may take the *Terrible* as a type. This vessel had a length of 226 feet, a breadth of 43 feet, a displacement of about 3,000 tons, and an indicated horse-power of 1,950. Her armament consisted of seven 68-pounders of 95 cwt., four 10-inch guns, ten 8-inch guns, and four light 32-pounders.

It will be observed that in these armaments there has been a very considerable increase in the weight of the guns carried. As I have said, the heaviest guns carried by the *Victory* were the 42-pounders of 75 cwt., but in these later armaments the 68-pounder of 95 cwt. is in common use, and you will have noted that the carronades have altogether disappeared. But as regards improvements in guns or mounting, if we except the pivot-guns, with respect to which there was some faint approach to mechanical contrivance to facilitate working, the guns and carriages were of the rude description to which I have alluded.

In one respect, indeed, a great change had been made. Shell-fire had been brought to a considerable state of perfection, and the importance ascribed to it may be traced in the number of 10-inch and 8-inch shell-guns which entered into the armament of the *Duke of Wellington* and the other ships I have mentioned. Moorsom's concussion fuse and other similar contrivances lent great assistance to this mode of warfare, and its power was soon terribly emphasised by the total destruction of the Turkish squadron at Sinope by the Russian fleet. In that action shell-fire appears to have been almost exclusively used, the Russians firing their shell with rather long-time fuses in preference to concussion, with the avowed object of there being time before bursting to set fire to the ship in which they lodged.

It is curious to note in the bygone discussions relative to shell-fire the arguments which were used against it; among others it was said that the shell would be more dangerous to those who used them than to their enemies. There was some ground for this contention, as several serious catastrophes resulted from the first attempts to use fused shells. Perhaps the most serious was that which occurred on board H.M.S. *Theseus*, when seventy 36 and 24-pounder shells captured from a French store ship and placed on the quarter-deck for examination exploded in quick succession, one of the fuses having by some accident been ignited. The ship was instantly in flames; the whole of the poop and after-part of the quarter-deck were blown to pieces. The vessel herself was saved from destruction with the greatest difficulty, and forty-four men were killed and forty-two wounded.

This accident was due to a neglect of obvious precautions, which would hardly occur nowadays, but I have alluded to the circumstance because the same arguments, or arguments tending in the same direction, are in the present day reproduced against the use of high explosives as bursting charges for shells. To this subject I myself and my friend and fellow labourer, Mr. Vavasseur, have given a good deal of attention, and the question of the use of these shells and the best form of explosive to be employed with them is, I believe, receiving attention from the Government. The importance of the problem is not likely to be overrated by those who have witnessed the destruction caused by the bursting of a high explosive shell, and who appreciate the changes that by their use may be rendered necessary, not only in the armaments, but even in important constructional points of our men-of-war.

Shortly before the termination of the long period of peace which commenced in 1815, the attention of engineers and those conversant with mechanical and metallurgical science seems to have been strongly directed towards improvements in war material. It may easily be that the introduction of steam into the navy may have had something to do with the beginning of this movement, but its further progress was undoubtedly greatly accelerated by the interest in the subject awakened by the disturbance of European peace which commenced in 1854.

Since that date—whether we have regard to our vessels of war, the guns with which they and our fortresses are armed, the carriages upon which those guns are mounted, or the ammunition they employ—we shall find that changes so great and so important have been made that they amount to a complete revolution. I believe it would be more correct to say several complete revolutions. It is at least certain that the changes which were made within the period of ten years following 1854, were far more important and wide-spreading in their character than were all the improvements made during the whole of the great wars of the last and the commencement of the present century.

Indeed, it has always struck me as most remarkable that during the long period of the Napoleonic and earlier wars, when the mind of this country must have been to so large an extent fixed on everything connected with our naval and military services, so little real progress was made.

Our ships, no doubt, were the best of their class, although, I believe, we were indebted for many of our most renowned models to vessels captured from our neighbours. They were fitted for sea with all the resources and skill of the first seamen of the world, and when at sea were handled in a manner to command universal admiration. But their armaments were of the rude nature I have described, and so far as I can see possessed little, if any, advantage over those of nearly a couple of centuries earlier. It is not improbable that the great success which attended our arms at sea may have contributed to this stagnation.

The men who with such arms achieved such triumphs, may well be forgiven for believing that further improvement was unnecessary, and it must be remembered that the practice of engaging at very close quarters minimised to a great extent the most striking deficiencies of the guns and their mountings.

I need scarcely, however, remind you that were two vessels of the old type to meet, one armed with her ancient armament, the other with modern guns, it would be vain for the former to attempt to close. She would be annihilated long before she approached sufficiently near to her antagonist to permit her guns to be used with any effect.

It would be quite impossible, within reasonable limits of time, to attempt to give anything like an historical account of the changes which have taken place in our ships of war during the last thirty-five years, and the long battle between plates and guns will be fresh in the memory of most of us. The modifications which the victory of one or the other impressed on our naval constructions are sufficiently indicated by the rapid changes of type in our battle-ships, and by the number of armour-clads once considered so formidable, but seldom now mentioned except to adorn the tale of their inutility. The subject also requires very special knowledge, and to be properly handled must be dealt with by some master of the art, such as our Director of Naval Construction.

Let me now compare with the vessels of the past those of the present day, and for my purpose I shall select for comparison as first-rates the *Victoria* and the *Trafalgar*. The *Victoria* has a length of 340 feet, a breadth of 70 feet; she has a displacement of about 10,500 tons, an indicated horse-power of 14,244, and she attained a speed on the measured mile of 17½ knots; she has a thickness of 18 inches of compound armour on her turrets, a similar thickness protects the redoubt, and her battery-deck is defended with 3-inch plates. Her armament consists of two 16¼-inch 110-ton guns, one 10-inch 30-ton gun, twelve 6-inch 5-ton guns, twelve 6-pounder and nine 3-pounder quick-firing guns, two machine-guns, and six torpedo-guns.

The *Trafalgar* has a length of 345 feet, or very nearly double the length of the *Victory*, a displacement of 12,000 tons, an indicated horse-power of 12,820, and a speed on the measured mile of a little over 17¼ knots. Her armament consists of four 68-ton guns, six 4·7-inch quick-firing guns, six 6-pounder, and nine 3-pounder quick-firing guns, six machine and six torpedo guns.

Comparing the armament of the *Victoria* with that of the *Victory* we find, to quote the words of Lord Armstrong—which when evaluating the progress we have made will bear repetition—that while the heaviest gun on board the *Victory* was a little over 3 tons, the heaviest on board the *Victoria* is a little over 110 tons. The largest charge used on board the *Victory* was 10 lbs., the largest on board the *Victoria* close on 1,000 lbs.; the heaviest shot used in the *Victory* was 68 lbs., in the *Victoria* it is 1,800 lbs. The weight of metal discharged from the broadside of the *Victory* was 1,150 lbs., from that of the *Victoria* it is 4,750 lbs. But having regard to the energy of the broadside, the power of each ship is better indicated by the quantity of powder expended than by the weight of metal discharged, and while the broadside fire from the *Victory* consumed only 355 lbs. of powder, that from the *Victoria* consumes 3,120 lbs.

These figures show in the most marked manner the enormous advances that have in every direction been made in the construction and armament of these marine monsters; but it is when we come to the machinery involved in our first-rates that the contrast between the past and the present is brought most strongly into prominence.

I have alluded to the simplicity of the arrangements on board the old battle-ships, but no charge of this nature can be made against the present. The *Victoria* has no less than twenty-four auxiliary steam-engines in connection with her main engines, viz., two starting, two running, eight feed, eight fan, for forced draught, and four circulating water engines. She has in addition thirty steam-engines unconnected with her propelling engines, viz., six fire and bilge engines, two auxiliary circulating engines, four fan engines for ventilating purposes, two fresh-water pumping engines, two evaporative fuel engines, one workshop, one capstan, and five electric-light engines, four air-compressing and three pumping engines for hydraulic purposes.

She has further thirty-two hydraulic engines, including two steering engines, four ash-hoisting engines, two boat engines, four ammunition lifts, two turret-turning engines, one topping winch, two transporting and lifting engines, two hydraulic bollards, and fourteen other engines for performing the various operations necessary for the working of her heavy guns, making a grand total of eighty-eight engines. This number is exclusive of the machinery in the torpedo and other steam-boats, and of the locomotive engines in the torpedoes carried, which are themselves engines of a most refined and delicate character.

At an earlier point in my address I alluded to the incomparable seamanship of our bygone naval officers. Seamanship will, I fear, in future naval battles no longer play the conspicuous part it has done in times past. The weather gage will belong not to the ablest sailor, but to the best engineer and fastest vessel, but the qualities of pluck, energy, and devotion to their profession which distinguished the seamen of the past have, I am well assured, been transmitted to their descendants, and I am glad to have the opportunity of expressing my admiration of the ability and zeal with which the naval officers of the present day have mastered, and the skill with which they use, the various complicated, and in some cases delicate machinery which mechanical engineers have placed in their hands.

I pass now to a class of vessel—the fast protected cruisers—intended to take the place and perform the duties of the old frigates. Of these I will take as types H.M.S. *Medusa* and the Italian cruiser *Piemonte*. The *Medusa* has a length of 265 feet, a breadth of 41 feet, a displacement of 2,800 tons, and her engines have 10,010 indicated horse-power. Her armament consists of six 6-inch breech-loading guns, ten 3-pounders, four machine-guns, and two fixed and four turning torpedo tubes. The *Piemonte* has a length of 300 feet, a breadth of 38 feet, a displacement of 2,500 tons, and her engines of 12,981 indicated horse-power developed on the measured mile a speed of 22·3 knots or about 26 miles. Her armament, remarkable as being the first instance of an equipment composed altogether of quick-firing guns, consists of six 6-inch 100-pounders, and six 4·7-inch 45-pounders, all with large arcs of training, ten 6-pounder Hotchkiss, four Maxim-Nordenfelt machine-guns, and three torpedo guns.

These vessels have a steel protective deck, with sloping sides from stem to stern, protecting the vitals of the ship; above and below the armour deck the vessels are subdivided into a large number of water-tight compartments, and a portion of the vessel's supply of coal is employed to give additional protection.

With respect to the *Piemonte* the engines (vertical triple expansion) were designed and constructed by Messrs. Humphreys, Tennant, & Co. They are, in order that they may be wholly below the water line, of exceedingly short stroke

(27 inches), and the behaviour of the engines, both on their trials here and in the very severe weather to which the vessel was exposed on her passage out, amply justify these eminent engineers in their somewhat bold experiment.

I might describe other cruisers, both larger and smaller than those I have selected, but I must not fatigue you, and will only in this part of my subject draw your attention to these triumphs of engineering ingenuity and skill, I mean the torpedo boats, which (whether or not locomotive torpedoes continue to hold their own as engines of destruction) are destined, I believe, to play no insignificant part in future naval warfare.

Let me illustrate the marvels that have been achieved by the great English engineers who have brought these vessels to their present state of perfection by giving you a few particulars concerning one or two of them.

A first-class torpedo boat by Yarrow has a length of 135 feet, a breadth of 14 feet, a displacement of 88 tons, and with engines of 1,400 indicated horse-power attains a speed of a little over 24 knots.

A slightly larger boat, built for the Spanish Government by Thorneycroft, has a length of 147 feet 6 inches, a breadth of 14 feet 6 inches, and with engines of 1,550 indicated horse-power has attained a speed of a little over 26 knots.

It is interesting to note that the engines of the first-named torpedo boat develop nearly exactly the same power as those of the 90-gun ship, the *Cæsar,* and the engines of the second-named but little less than that developed by the *Duke of Wellington,* two vessels which you will remember I have taken as types of the second- and first-rate men-of-war of thirty-five years ago.

The weight of the engines of the *Duke of Wellington* and the *Cæsar* would be approximately 400 tons and 275 tons, while that of the torpedo boats is about 34 tons.

But if these results are sufficiently remarkable, the economy attained in the consumption of coal is hardly less striking.

The consumption of coal in the early steam battle-ships was from 4 to 5 lbs. per indicated horse-power per hour, and occasionally nearly reached 8 lbs.

At the present time in good performances the coal consumption ranges from $1\frac{1}{2}$ to $1\frac{3}{4}$ lbs. per indicated horse-power per hour under natural draught, and from 2 to $2\frac{1}{4}$ lbs. per hour with forced draught.

In war-ships the engines are designed to obtain the highest possible power on the least possible weight, and this for a comparatively short time, and, further, have to work at such various powers, that the question of economy must be a secondary consideration.

With the different conditions existing in the mercantile marine, more economical results may be expected, and I believe I shall not be far wrong in assuming that in special cases $1\frac{1}{3}$ lbs. may possibly have been reached; but I have not been able to obtain exact information on this head.

Turning now to the guns, let me refer first to those which were in use thirty-five years ago, and which formed the armaments of the ships of those days, and of the fortresses and coast defences of the United Kingdom and colonies.

The whole of these, with the exception of a few very light guns, were made of cast-iron. I have already alluded to the small amount of machine work (not of a very refined character) expended on them. Although the heaviest gun in use was only a 68-pounder, there were no less than sixty different natures of iron ordnance. Of the 32-pounder alone there were as many as thirteen descriptions, varying in length and weight. Of these thirteen guns, again, there were four separate calibres ranging from 6·41 inches to 6·3 inches, and as the projectile was the same for all, the difference fell on the windage. This varied, assuming gun and projectile to be accurate, from about 0·125 to 0·250, so that it may easily be conceived the diversity of the tables of fire for this calibre of gun were very great. And although from the simple nature of the guns, and the absence of anything like mechanical contrivance connected with them, it was quite unnecessary to give to them the care and attention that are absolutely indispensable in guns of the present day, it must not be supposed that they were altogether free from liability to accident and other defects.

I had occasion recently to look into the question of the guns employed in the siege of Sebastopol, and found that in that great siege no less than 317 iron ordnance were used by this country. At the close of the siege it was found that 8 had burst, 101 had been condemned as unserviceable, while 59 were destroyed by the enemy's fire.

The 95 cwt. 68-pounder gun seems to have been about the largest gun that could safely be made of cast-iron, and that in it the limit of safety was nearly reached, was shown by the fact that a serious percentage of this calibre burst or otherwise failed. With the spherical shot the column of metal per unit of area to be put in motion by the charge was small, and to this the guns probably owed their safety.

When the same charge was used, and cylinders representing double, treble, or quadruple the normal weight of the shot were fired, the end was rapidly reached, the guns frequently bursting before cylinders four or five times the weight of the shot were employed.

But the fact that a stronger and more reliable material than cast-iron was necessary, was shortly to be emphasised in a much more striking manner. The great superiority of rifled to smooth-bored ordnance in every respect, in power, in range, in accuracy, in destructive effect of shrapnel and common shell, was in this country demonstrated by Lord Armstrong and others. This led to numerous attempts to utilise cast-iron for rifled ordnance. The whole of these efforts resulted in failure. Although the charges were feebler than with smooth-bored guns, these experimental guns burst one after the other with alarming rapidity, generally before many rounds had been fired. The matter was not made much better when the expedient was adopted of strengthening these guns by hoops or rings shrunk on externally. Failures with this arrangement were little less frequent, the cast-iron bursting under the jackets, and the only plans in which cast-iron was used with any success were those proposed respectively by Sir W. Palliser and Mr. Parsons, who inserted, the one a coiled wrought-iron, and the other a steel tube in a cast-iron gun block.

But the country that suffered most severely from the use of cast-iron was the United States. Their great civil war took place just when efforts were being made in every country to introduce rifled artillery. Naturally every nerve was strained to manufacture these guns, and naturally the resources that came most readily to hand were first employed.

A report presented by the Joint Committee on Ordnance to the United States Senate in 1869 gives the history of these guns, which were nearly all either cast-iron or cast-iron reinforced with hoops in the way I have described. I have heard the existence of internal strains disputed, but in this report we read that ten guns burst, that is flew to pieces, when lying on chocks, without ever having had a shot fired from them, and 98 others cracked or became ruptured under like conditions.

In the 'Summary of Burst Guns' in the same report, it is stated that 147 burst and 21 were condemned as unserviceable; 29 of them being smooth-bore and 139 rifled ordnance. But perhaps the most striking passage is that which relates that in the action before Fort Fisher *all* the Parrott guns in the fleet burst, and that by the bursting of five of these guns during the first bombardment, 45 men were killed and wounded, while only 11 men were killed or wounded by the enemy's fire.

The muzzle velocity given by the smooth-bored, cast-iron guns may be taken approximately at 1,600 f. s., and at the maximum elevation with which they were generally fired their range was about 3,000 yards. The 32-pounder, with a charge of one-third the weight of the shot and an elevation of 10°, gave nearly 2,800 yards, and the 68-pounder, with a charge of about one-fourth, nearly 3,000 yards. The same gun, with an eccentric shot, and an elevation of 24°, gave a maximum range of 6,500 yards.

But it must not be supposed because the range tables gave 3,000 yards as practically the extreme range of the ordnance of 35 years ago, that our guns possessed any high efficiency at that distance. At short distances, from 300 to 500 yards, dependent on the calibre, the smooth-bored guns were reasonably accurate, but the errors multiplied with the distance in so rapidly increasing a ratio that long before a range of 3,000 yards was attained the chance of hitting an object became extremely small.

It is desirable to give some idea of the accuracy, or rather want of accuracy, of these guns.

In 1858 I was appointed secretary to the first Committee on Rifled Cannon, and the early experiments showing how extraordinary was the accuracy of the new weapons, it became a matter of importance to devise some means of comparing in this respect the old and the new guns.

The plan I proposed was one which has since been followed by the artillerists of nearly all countries. It was to calculate the probable error in range and the probable error in deflection, and from these data the area within which it would be an even chance that any given shot would strike; or, in other words, that area within which, out of a large number of rounds, half that number would fall. This area was for the smooth-bored gun at a range of 1,000 yards, 147·2 yards long by 9·1 yards broad, or 1,339·5 square yards, while the similar area for the rifled gun at the same range was 23·1 yards long by 0·8 yard broad, or an area of 18·5 square yards. But the great decrease of accuracy due to an increase of range with the smooth-bore guns is especially remarkable. Experiments showed that with the smooth-bored gun an increase of range of only 350 yards more than doubled the error in deflection, and made the area selected for comparison 206 yards long by 20·2 broad, or 4,161 square yards, as nearly as possible trebling the area for an increase in range of 35 per cent.

But I have not done yet. These experiments were made with the same lots of powder carefully mixed, and the irregularities in velocity would be such as are due to manufacturers' errors only. But the variations in the energy developed by the gunpowder employed have still to be considered. In 1860, being then an associate member of the Ordnance Committee, I carried on for the Government the first electro-ballistic experiments made in this country. My attention was early called to the great variation in energy developed by powders recently made and professedly of the same make, and I pointed out that in my experiments the variations between one lot of powder and another amounted occasionally to 25 per cent. of the total energy developed. It is unnecessary to say that on service, and when powder had been subjected to climatic influences, the variations would have been much greater.

The variations in energy of new powder were chiefly due to the method of proof then in use, the Eprouvette mortar, than which nothing can be conceived better adapted for passing into the service powders unsuitable for the guns of that time.

But with the want of accuracy of the gun itself, and the want of uniformity in the propelling agent, it may easily be conceived that a limit was soon reached beyond which it was mere waste of ammunition to fire at an object even of considerable size, and we can appreciate the reasons which led our naval commanders, whenever possible, to close with their enemy.

When we come to consider guns of the present day, the first point that attracts our attention is the enormous increase in the size and weight of the larger natures. It may fairly be asked indeed if, weight for weight, the modern guns are so much more powerful than the old, and, if we have command of such great ranges, why such heavy guns should be necessary.

The answer to this, of course, is that it has been considered essential to have guns capable of piercing at short distances the thickest armour which any ship can carry, and this demand has led us from guns of 5 tons weight up to guns of 110 and 120 tons weight, and to the development of the important mechanical arrangements for working them, to which I shall presently refer.

On the principles which guide the construction of these large guns I shall say little, both because the subject is too technical to be dealt with in an address, and because the practice of all nations, though differing in many points of detail, in essentials is closely accordant.

On three points of construction we lay particular stress in this country. These points are: That the gun shall be strong enough to resist the normal working pressure, even if the inner tube or barrel be completely split; that whether we regard the gun as a whole, or the parts of which it is composed, the changes of form should be as little abrupt as possible; and that any sharp angle or corner must be absolutely avoided.

As in principles of construction, so in material employed, is the practice of the great gun-making nations closely agreed. The steel employed is ductile and subjected to severe specifications and tests, which differ slightly one from the other, but exact, in effect, qualities of steel substantially the same. So far as I know, the application of the tests in this country is more severe than in any other, and I take this opportunity of entering my protest against the statement which I have seen more than once in the journals of the day—that English gun-steel is in any way inferior to any that is produced in any part of the world. Sheffield has in no respect lost its ancient reputation in the art of steel-making, and to my certain knowledge has supplied large quantities of steel, admitted to be of the first quality, to gunmakers of the Continent. The steel made by Sir J. Whitworth & Co. has likewise long been in great repute both at home and abroad, and looking at the care devoted to the subject by the Government, and the eagerness with which improvements in the quality and mode of manufacture are sought for and acted on by the steel-makers, we may be absolutely certain that to the best of our knowledge the most suitable material is used in the construction of our guns.

As many of you are aware, the mild steel which is used for the manufacture of guns is after forging and rough-boring subjected to the process of oil-hardening, being subsequently annealed, by which process it is intended that any detrimental internal strain should be removed. This process of oil-hardening, introduced first by Lord Armstrong in the case of barrels, is now almost universally adopted for all gun forgings. Of late, however, there has been considerable discussion as to whether or not this oil-hardening is necessary or desirable; and while admitting the increase of the elastic limit due to the process, it is asked whether the same results would not be obtained by taking a steel with, for example, a higher percentage of carbon, and which should give the same elastic limit and the same ductility. The advocates of oil-hardening urge that steel with low carbon, duly oil-hardened to obtain the elastic limit and strength desired, is more reliable than steel in which the same results are reached by the addition of carbon. Those who maintain the opposite view point to the uncertainty of obtaining uniform results by oil-hardening, to the possibility of internal strains, and to the costly plant and delay in manufacture necessary in carrying it out. The question raised is undoubtedly one of great importance, but it appears to me to be one concerning which it is quite within our power in a comparatively short time, by properly arranged experiments, to arrive at a definite conclusion.

Sir F. Abel has in his Presidential Address given us so masterly a *résumé* of the present state of the steel question in its metallurgical and chemical aspects that it is unnecessary for me to add anything on this head. I will only remark that in selecting steel for gun-making, individually I should prefer that which is on the side of the low limit, to that which is near the high limit, of the breaking weight prescribed by our own and other Governments. I have this preference because, so far, experience has taught us that these lower steels are safer and more reliable than the stronger —and in guns we do not subject, and have no business to subject, the steel to stresses in any way approaching that which would produce fracture.

Of course if our metallurgists should give us a steel or other metal which with the same good qualities possesses also greater strength, such a material would by preference be employed, but it must not be supposed that the introduction of such new material would enable us, to any great extent, to reduce the weight of our guns. As a matter of fact, the energy of recoil of many of our guns is so high that it is undesirable in any case materially to reduce their weight. As an illustration I may mention that some time ago in re-arming an armour-clad, the firm with which I am connected was asked if by using the ribbon construction it would be possible, while retaining the same energy in the projectile, to reduce the weight of the main armament by three tons per gun. The reduction *per se* was quite feasible, but when the designs came to be worked out it was found that, on account of the higher energy of recoil, no less than four tons weight per gun had to be added to strengthen the mounting, the deck, and the port pivot fastenings.

The chamber pressures with which our guns are worked do not generally exceed seventeen tons per square inch, or say 2,500 atmos. It must not be supposed that there is any difficulty in making guns to stand very much higher initial tensions; but little would be gained by so doing. Not only can a higher effect be obtained from a given weight of gun if the initial pressure be kept within moderate limits, but with high pressures the erosion (which increases very rapidly with the pressure) would destroy the bores in a very few rounds.

In fact, even with the pressures I have named, the very high charges now employed in our large guns (1,060 lbs. have frequently been fired in a single charge), and the relatively long time during which the high temperature and pressure of explosion are maintained, have aggravated to a very serious extent the rapid wear of the bores. In these guns, if the highest charge be used, erosion, which no skill in construction can obviate, soon renders repair or relining necessary. Reduced charges, of course, allow a materially prolonged life of the bore, and there is also a very great difference in erosive effect between powders of different composition, but giving rise in a gun to the same pressures. Unfortunately, the powder which has up to the present been found most suitable for large guns is also one of the most erosive, and powder-makers have not so far succeeded in giving us a powder at once suitable for artillery purposes, and possessing the non-eroding quality so greatly to be desired.

An *amide* powder made by the Chilworth Company, with which I have, not long ago, experimented, both gave admirable ballistic results, and at the same time its erosive effect was very much less than that of any other with which I am acquainted. It is by no means certain that the powder would stand the tests which alone would justify its admission into the service, but the question of erosion is a very serious one, and has hardly, I think, received the attention its importance demands. No investigation should be neglected which affords any prospect of minimising this great evil.

On the introduction of rifled artillery the muzzle velocities, which you will remember had been with smooth-bore guns and round shot about 1,600 f. s., were, with the elongated projectiles of the rifled gun, reduced to about 1,200 f. s. In the battle between plates and guns these velocities were with armour-piercing projectiles gradually increased to about 1,400 f. s., and at about this figure they remained until the appointment by the Government of a Committee on Explosives. By the experiments and investigations of this committee it was shown that, by improved forms of gunpowder and other devices, velocities of 1,600 f. s. could be obtained without increasing the maximum pressure, and without unduly straining the existing guns. Similar advances in velocity were nearly simultaneously made abroad, but in 1877 my firm, acting on independent researches on the action of gunpowder made by myself in conjunction with Sir F. Abel, constructed 6-inch and 8-inch guns which advanced the velocities from 1,600 to 2,100 f. s., and this great advance was everywhere followed by a reconstruction of rifled artillery.

With the present powder the velocities of the powerful armour-piercing guns, firing projectiles considerably increased in weight, may be taken at from 2,000 to 2,100 f. s. The distance of 3,000 yards, which I said practically represented the extreme range of smooth-bored guns, is attained with an elevation of only 2° in the case of the 68-ton gun, and of 3½° in the 4·7-inch quick-firing gun, while at 10° the ranges are 9,800 and 5,900 yards respectively, and, as an instance of extreme range, I may mention that with a 9·2-inch gun a distance of over 13 miles has actually been reached.

Nor is the accuracy less remarkable. Bearing in mind the mode of comparison which I have already explained, at 3,000 yards range the 68-ton gun would put half its shot within a plot of ground 7·2 yards long by 0·3 broad, and the 4·7-inch gun within a plot 19 yards long by 1·3 broad; or, to put it in another form, would put half their rounds in vertical targets respectively 0·92 yard broad by 0·34 yard high and 1·3 yards broad by 1·6 yards high.

But it cannot be assumed that we are at the end of progress. Already, with the amide powder we have obtained nearly 2,500 f. s. in a 6-inch gun with moderate chamber pressures, and with the cordite originated by the Committee on Explosives, of which Sir F. Abel is president, considerably better results have been obtained. I have elsewhere pointed out that one of the causes which has made gunpowder so successful an agent for the purposes of the artillerist is that it is a mixture, not a definite chemical combination; that it is not possible to detonate it; that it is free, or nearly so, from that intense rapidity of action and waves of violent pressure which are so marked with nitro-glycerine and other kindred explosives.

We are as yet hardly able to say that cordite in very large charges is free from this tendency to detonation, but I think I may say that up to the 6-inch gun we are tolerably safe; at least, so far, I have been unable, even with charges of fulminate of mercury, to produce detonation. I need not remind you that cordite is smokeless, and that smokeless powder is almost an essential for quick-firing guns, the larger classes of which are day by day rising in importance.

I now come to the third part of my subject—the modes which are now adopted of mounting and working the ordnance I have described. I have alluded to the carriages, which, at the beginning of the century, were made of wood, and were worked solely by handspikes. Thirty-five years ago they were but little changed, although in the case of pivot guns screws for giving elevation, and blocks and tackle for training had been introduced, but timber was still the material employed. A strong prejudice long existed in both services against iron for gun carriages, as it was believed that iron carriages would be more difficult to repair, and that the effect on the crew of splinters would be much more serious.

But when the experiment of firing at both types was made at Shoeburyness, with dummies to represent the crews, it was found both that the wooden carriage was far more easily disabled than the wrought iron, and that the splinters from the wooden carriages were far more destructive.

In all other respects, the superiority of wrought iron as regards unchangeability, durability, and strength, was so apparent, that iron, and later steel, rapidly displaced wood. No gun carriages, not even field, are now made of that material. It is impossible, within moderate limits, to give even a sketch of the various forms of mountings that have, as the science of artillery has progressed, been designed to meet the constantly changing conditions of warfare. I shall confine myself to the description of certain types of carriages, dividing these generally into three classes, viz., those for guns of the largest class, which require power to work them; those for guns of medium size, in which, by special arrangements, power is dispensed with; and those for guns of a smaller class, which are particularly arranged for extremely rapid fire.

With respect to the first class. On the adoption of heavily armed, revolving turrets of the Cowper-Coles type, in which the guns are trained for direction by revolving the turret, the first idea which naturally presented itself was to utilise steam power for this heavy work. It was, however, soon recognised that, on account of its elasticity steam did not give the necessary steadiness and control of movement essential for accuracy of aim, and water under pressure was employed as the means of transmitting the power from the steam-engine to the machinery for rotating the turret and working the guns.

On land, where an accumulator can be employed, a small steam engine kept constantly at work is used; but at sea, where accumulators, whether made to act by the pressure of steam, air, or springs, are inadmissible, a very much larger engine is employed sufficiently powerful to supply water to perform all the operations ever carried on together. When little or no work is required, the engine automatically reduces its speed till it merely creeps, so that little or no power is consumed.

The mode of mounting the guns differs somewhat according as they are intended to be placed in a barbette or in a turret. Our guns have gradually been increasing in length, and are now so long (our largest has a length of nearly 45 feet) that it is impossible to provide an armoured turret of sufficient size to protect the forward part of the gun, and under these circumstances it is a grave question whether it is worth while to devote so much armour to the protection of what is after all the strongest part of the gun

Of the eight new battle-ships now building, seven are to have their guns mounted *en barbette*, and one is to be provided with armoured turrets. In either case the guns and their machinery are carried on revolving turntables of practically the same form. These turntables are placed in an armoured redoubt, and the guns, when horizontal, are entirely above the armour; but in the case of the ship provided with turrets the breech ends of the guns are covered in, with the turrets placed as an addition on the turntables.

The extra weight required thus to protect the breech ends of the guns is for this ship about 550 tons.

As the hydraulic machinery for these new ships differs but slightly from that fitted on ships of the *Rodney* and *Nile* classes, the same description will cover all these vessels. The armoured barbette battery at each end of the ship is made of a pear shape, as seen in plan, in order to provide for a pair of ammunition hoists and hydraulic rammers at its narrower end.

These ammunition hoists come right up into the armoured barbette and descend to the shell-room and magazine decks, forming the channel by which the projectiles and charges are rapidly supplied to the guns; and it must be remembered that the weight to be lifted for a single round, including powder and projectile, with the necessary cases, considerably exceeds a ton. The cage in each hoist is worked by hydraulic cylinders with double wire-ropes, and in case of breakage, automatic safety gear is fitted to arrest and lock the cage.

While on the ammunition deck the cages are charged simultaneously from either side, and when hoisted to the battery-deck are automatically slowed, and then stopped at the proper position for loading the guns. Much depends upon the service of ammunition by these hoists being protected from interruption, and in the event of derangement of the cage, independent tackle, worked by an hydraulic capstan, is provided to take its place, and a few rounds can also be stowed within the battery.

In intimate connection with the ammunition hoists are the hydraulic rammers on the ammunition deck for charging the cages, and in the battery for loading the guns. To reduce their length within reasonable limits they are made telescopic, and they are fitted with indicators to show when the charges are home.

In the shell-rooms hydraulic cranes and traversing bogies are fitted to convey the shell to the base of the ammunition hoist, so that a projectile is transported from the place where it is stowed to the shot-chamber of the gun without manual labour of any sort except that of moving the various levers to set the hydraulic machinery in motion. In the magazines hydraulic bollards are provided for hoisting and transporting the powder-cases by means of overhead runners. Hand-gear is provided as an alternative in both magazine and shell-rooms.

Each turntable carrying the guns and their fittings is rotated by a pair of entirely independent three-cylindered engines, each engine being of sufficient power to rotate the turntable at the speed of one revolution per minute. The gear for controlling them is worked from two or three look-out stations, at either or any of which the officer has to his hand the means of elevating, training, sighting, and firing either one or both guns. The turning-engines are fitted with a powerful spring break, which will hold in a seaway, but which is taken off automatically when the water is admitted to start the engines. Easy control is obtained by the use of servo-motor valves, so that the handwheel is small and requires but little power to move it. It only remains to describe as shortly as possible the system of mounting the guns on the turntable. The guns are trunnionless, to allow them to be as close together as possible, with the view of reducing to the smallest possible size the diameter of the turntables. The carriages are cradles of steel grooved to correspond with rings turned on the guns, and with straps by which the guns are secured to the cradles. The carriages are mounted without rollers or wheels on slides formed of steel beams of great strength, pivoted at their front ends and supported on hydraulic presses by which they are bodily raised or lowered to give the guns elevation or depression. In the case of the turret this system gives the smallest possible port. The loading of the gun is effected while the gun is at extreme elevation, a position which is easily determined by dropping the slide on to fixed stops, and which gives the best protection for the breech mechanism, for the hoist and rammers. The operations of unlocking the breech-block, withdrawing it, traversing it, inserting a loading tray, and, after completing the loading, performing the same operations in reverse order, are all done by hydraulic power, and the fittings are so devised that unless the gun is properly locked and run out it cannot be fired.

In certain foreign vessels provided with the hydraulic breech mechanism, a valve has been arranged which makes in their proper order, and in that order only, the eight or ten movements necessary to open and close the breech of the gun; but this system has not been adopted in our own navy.

The sights are carried on the top of the turntable, or, in the case of a turret, on the turret roof, and are worked automatically by an arc attached to the gun slide, gearing into cog-wheels, with shafting reaching to each sighting position.

The system of recoil press adopted on all these ships is that which lends itself most readily to employment also as a running-in-and-out press. It consists of a simple cylinder carried in the middle of the slide, having working in it a ram with piston, attached at the front end to the carriage. Spring-loaded valves are placed in the recoil ram piston and at the end of the cylinder, and by these the water escapes when the gun recoils. The water which passes through the cylinder valves runs to the exhaust-pipe, while that which passes through the piston valve remains in the front of the cylinder, and prevents the gun charging out again. When the recoil press is used to run the gun in and out these valves are inoperative, as they are loaded much above the working pressure in the hydraulic mains. The high pressure of recoil does not enter the hydraulic mains, as the supply to the rear of the press, where alone the high pressure of recoil exists, is made backwards and forwards, through a valve which shuts itself automatically when not in use.

Before leaving the working by power of heavy guns, there is one example of mounting a pair of guns *en barbette* which, although it has many points in common with the system I have just described, has also some points of difference, which it may be worth while to note.

Objections have sometimes been urged to the fixed loading station on the ground that it is necessary to bring the guns to it and lock them there until sponged and loaded, thereby involving, not only a loss of time, but under certain conditions exposing them more to the enemy's fire.

In ships of the *Re Umberto* type, what is termed an all-round loading is obtained by bringing up the ammunition through a central hoist to the deck below the turntable. From this central hoist it is transferred to two other hoists, which are carried on the turntable behind the guns. The transfer is made by hand for the powder and by sliding down a tray for the projectile, this work being performed by men on the deck below the turntable. The hydraulic rammers are fixed to the turntable, and are very much shortened by being made with more rams. In spite of this arrangement, however, the hoists are rather cramped, and the breech mechanism has to be made to pass from behind the gun, so as to permit the gun to recoil, and the gun is rather further forward than usual when run out.

With these reservations, however, the system has advantages: the reduction in the armour required to protect the turntable and its machinery is considerable, and the redoubt being round instead of pear-shaped presents a smaller and stronger surface to the enemy when broadside on.

I very much doubt, however, whether with this system there can be any advantage in rapidity of fire. Training to the loading station is in our navy very quickly done, and the turntable is rotated while the guns are being run in or out.

It is hardly necessary to say that hydraulic machinery for guns was worked out by my friend and late partner Mr. George Rendel, and up to the end of 1881 all details connected therewith were made under his management.

I ought perhaps to give you some idea of the rate at which these heavy guns worked by power can be fired.

In the case of the *Benbow*, with the 110-ton gun the time from 'load' to 'ready' was 2½ minutes. In the firing trials of the *Trafalgar* four rounds were fired from one of her 68-ton guns in 9 minutes 5 seconds. In the *Colossus*, when under command of Captain Cyprian Bridge, the average from one round to another was 1 minute 45 seconds, and on one occasion, steaming at 8 knots per hour past a target at a distance of 1,500 yards, she fired four rounds in six minutes, striking the target three times.

Of the mountings which are worked solely by manual power, the whole range for naval service is covered by the carriages of the type designed by Mr. Vavasseur. No single description can be made to cover all the varieties of these mountings which have been worked out to meet the diverse conditions which have arisen in the re-arming of old ships, and the fitting out of new vessels on modern and novel designs. The very general adoption of breechloading ordnance brought with it the necessity for a mounting which would give easier access to the breech of the gun than was obtained with the long low gun-slide employed with the muzzle-loading guns. The main features of the type therefore are, a high slide, very short, so as not to project beyond the breech of the gun, a short low carriage carrying on either side the recoil presses, and a shield to afford protection both to the carriage and the gun crew.

The increased importance of rapid-fire guns has led in later carriages to a strong armour plate being built into the mounting as part of its structure, and to this must be added the shield above mentioned, so that the total protective thickness of plate is very considerable.

By means of a worm wheel sliding on a keyed shaft the movement of the gun for elevation or depression can be made up to the instant of firing—a decided and very important advance on the older methods.

The arrangement of the recoil-cylinders is peculiar. They are fitted with a pair of pistons with rotating valves, so adjusted as to be open when the gun is in the firing position, and to be gradually closed during recoil by studs running along rifled grooves in the cylinders; by this ingenious contrivance the area of the ports of the valves is increased and then decreased in proportion to the variation of the velocity of recoil, so that the liquid passes from one side of the piston to the other at as nearly as possible a constant velocity and under a constant pressure. The velocity of the flow through the ports, and therefore the pressure of the liquid, varies with the energy of the recoil of the gun, so that the length of the recoil is with all charges practically the same.

Even a blank charge produces nearly full recoil, and on one occasion caused one of these mountings to be reported as unserviceable, and unfit to fire a shotted round. Constant length of recoil has the advantage over constant pressure in the recoil-presses that, in the event of an unusually heavy recoil, a higher pressure in the recoil-press would in the former case be the only result, and would do no harm, as the pressure would still be much below the test-pressure; but in the latter case there would be an increased length of recoil, and, unless considerable margin were allowed, a possible destruction of the slide.

Most frequently the Vavasseur mountings are made with central pivots, and there is then little tendency for the movements of the vessel to affect the mounting, and as the weight is borne upon a ring of live rollers the greatest ease of training is obtained.

In the larger sizes the centre pivot is increased in size, and made hollow so as to provide for the passage through the centres of a powder hoist, which, after rising high enough, curves to the rear under the gun and delivers its charge at the point where it can most conveniently be drawn out for insertion in the gun. In this case a foot plate is also provided as a rear attachment to the slide, and from this the crew work the gun. This foot plate is provided with boxes for eight or ten projectiles, which are therefore ready for use at any moment and in any position of training. These mountings are fitted in the belted cruisers of the *Orlando* class, one being carried at the fore and one at the after end of each ship.

As a sufficient proof of the value of these mountings and of the ability which has been displayed in their design, I may mention that practically all countries have adopted these carriages for modern guns, either without any alteration or with comparatively unimportant modification.

In discussing our modern ordnance I only alluded to quick-firing guns, because in their case the gun and mounting are so closely connected, the efficiency of the system depending as much upon the one as the other, that a separate description of either would be incomplete, and they are more easily described together. The great success which attended the small Hotchkiss and Nordenfelt three- and six-pounder guns led me to consider whether the same principle could not be applied to large guns, and we designed and made at Elswick the 4·7 inch and 5·5 inch quick-firing guns which were so successfully tried by the *Excellent* at Portsmouth. Subsequently, with the co-operation of Mr. Vavasseur, various improvements were made, and for the sake of uniformity in calibre a 6-inch was substituted for the 5·5-inch gun.

One of the peculiarities of these guns is in the form of the breech-screw, which, while on the principle of the interrupted screw, is made conical, so as to simplify the action of opening and closing—the principle of the ordinary rifle cartridge has been extended to the ammunition for these guns. This not only allows extremely rapid loading, but secures safety from premature explosions in rapid firing. The cartridges are fired electrically, and, not having their own ignition, there is no danger of exploding them either when stowed in the magazine or if accidentally dropped in the handling.

To follow the rapid movements of a torpedo boat it is essential that there should be the most perfect control over the gun and mounting, and the most effective mode of rapid fire is to keep the gun always on the object aimed at, allowing the gun itself to fire as the breech is closed. The captain stands at the side of the gun, shielded by a guard-plate from the recoil, his shoulders braced against a shoulder-piece which is unaffected by the recoil; his eye aligns the sights; with one hand he works the elevating or training wheel, and with the other grasps the firing-trigger, or, for rapid firing, the training-wheel may be thrown out of gear and direction given by the shoulder-piece alone. The mounting is a centre pivot, and, being on live rollers, turns with the least effort. The gun has no trunnions, but slides in a carriage which envelops it like a sleeve. The trunnions are on this carriage, so that the two are together pivoted like an ordinary gun in a fixed lower carriage. There is no preponderance when the gun is in the forward position, and the recoil lasts for so short a time that the disturbance of the centre of gravity is not felt on the elevating-gear or shoulder-piece. The lower side of the carriage is formed into a recoil press, the piston-rod of which is attached to a horn on the rear of the gun.

There is also a spring-box, with rod attachments to the horn, by which the gun is instantly run out as soon as the recoil is expended. Efficient shields are provided to protect the crew. The revolving weight of the gun and mounting is 5 tons, yet, with the shoulder against the shoulder-piece, it can be swung through 90° in 2 seconds, and with the gear can be trained through the same arc in 5 seconds. It is possible to fire from this gun at the rate of 10 to 12 rounds per minute, and on one occasion 10 rounds were fired in 47 seconds; but perhaps the most striking experiment with the gun was made at Shoeburyness, when 5 rounds were fired in 31 seconds at a 6′ × 6′ target at 1,300 yards, all of which struck the object aimed at.

A trial has also been recently made between two cruisers, the one armed with ordinary breech-loading, the other with quick-firing artillery, from which it appears that when firing at a target the latter, in a given time, was able to discharge about six times the quantity of ammunition fired by the former. I need not impress upon you the significance of these facts or the importance of quick-firing armaments, especially if firing shell, possibly charged with high explosives, against the unarmoured portions of cruisers or other vessels.

The accuracy and the shell power of rifled guns have naturally had their effect upon the mountings for the land service, experiments having conclusively shown that batteries armed with guns placed in ordinary embrasures would soon be rendered untenable. Among the expedients that have been adopted or suggested to meet the altered conditions, the system of making the gun disappear behind a parapet or into a pit, with which the name of Colonel Moncrieff has been so long and so honourably associated, is more and more coming into favour, as the most effective mode of protection for the gun and its mounting, as well as for the gun detachment. During the last ten years much attention has been devoted to the designing of various mountings on this system for all weights of guns from 3 up to 68 tons.

In the earliest carriages of this type the gun was raised by the descent of a balance weight, but the most successful arrangement is that in which compressed air is employed for the purpose. The 9·2-inch and 10-inch hydro-pneumatic mountings are the largest sizes as yet adopted into the English service, and a description of them will serve for that of the type generally.

The gun on this system is raised by compressed air stored in several chambers, and acting through the medium of a fluid upon a recoil ram.

On the recoil of the gun the liquid is driven from the cylinder by the incoming ram into the lower parts of the air chambers, so that as much as is required of the energy of recoil is stored up by the compression of the air, and is used to raise the gun for the next round. The gun is raised up and lowered on two heavy beams pivoted to the lower carriage. Two long light elevating rods, pivoted at one end to the breech of the gun, at the other to the lower carriage, hold the gun in correct position as it rises or falls; the elevation is changed by moving the position of the lower ends of the elevating rods. This can be done when the gun is down without disturbing it, and consequently with very little labour. The effect of the change is apparent after the gun rises, when any slight correction can be made if desired. Generally these mountings have been made with overhead shields placed a little below the level of the top of the gun pit, and entirely closing it. There is an aperture through which the gun rises, but which can be closed when the gun is out of action.

In the case of the 10-inch gun the total weight of the revolving mass is 80 tons. Only two men are required at the hand wheels to revolve it—in fact, it is within the power of *one* man to do the whole work. The ordinary speed of training is 90° in $1\frac{1}{4}$ minute, while the time required to raise the gun to the firing position is 20 seconds. The speed of rising might be considerably increased, but, taking the weight of the mass in motion into account, it does not appear to be desirable to accelerate it.

At Maralunga, Spezia, in March of the present year, the first 68-ton disappearing mounting, manufactured for the Italian Government, was tried with most satisfactory results. Fifteen rounds were fired in all, some of them being made to give greatly increased energy of recoil, with the view of proving the gun and mounting.

The gun was worked entirely by hand-power, and on land no difficulty is experienced in thus dealing with it, while the system possesses the advantage that it is always ready for use should it be required, but no great alteration is necessary to adapt the mounting for use with hydraulic power.

In this case the water from the recoil press is driven through spring-loaded valves instead of into air chambers. There is, therefore, no storing up of the recoil energy, and to raise the gun to the firing position, water pressure from an accumulator kept charged by a steam-pumping engine in the usual way is employed. These guns and mountings are too large to be easily covered by an overhead shield, but they are provided with shields at the front and rear to protect the gun detachments.

Another very successful mounting for land service has been made for guns when the site is such that it is permissible to place them *en barbette*. The gun is entirely above the parapet, but the detachment is protected while loading and working the gun by a broad sloping shield carried on the gun carriage and recoiling with it. The shield is inclined so that any splinters, &c., striking it may be deflected in an upward direction.

The carriage runs back on a long slide inclined at 5°, and at the end of the recoil is caught by a spring catch, which retains it in the run in position until the loading is finished. To load, the gun is put at extreme elevation, so that the breech may be as much under protection as possible, the charge being rammed home with a hand rammer worked by rope tackle. The slide is mounted on front and rear rollers, and has an actual centre pivot. The recoil is controlled by a single Vavasseur recoil cylinder placed in the centre of the slide, and giving a constant length of recoil for all charges, so that the spring catch to retain the gun at extreme recoil for loading is always reached.

To run out after loading, the spring catch is released, and the incline of the slide is sufficient to cause the gun to run out, which it does smartly, but is checked and brought to rest quietly by means of a controlling ram placed at the end of the recoil press.

But I must conclude. I trust I have said enough to satisfy you as to the indebtedness of the naval and military services to mechanicians and to mechanical science, but you will also understand that within the limits of an address it is impossible to give a complete survey of so large a subject, and that there are important fields I have left wholly untouched.

The following Papers were read:—

1. *A Hydraulic Steam Lifeboat.* *By* J. F. Green.

The author pointed out that, had it not been for the perfection now reached in the manufacture of mild steel and the invention of forced draught, the application of steam to the propulsion of a lifeboat would have been impracticable.

The boat described in this paper has recently been built by Messrs. Green, of Blackwall, for the National Lifeboat Association, and is stationed at Harwich. Her principal dimensions are as follows: Length, 50 ft. Beam, moulded, 12 ft. Extreme breadth, 14 ft. $3\frac{3}{4}$ in. Draft, when fully loaded, 3 ft. 6 in. Displacement, when fully loaded, 26 tons. Speed, when fully loaded, 9·367 knots. Indicated horse-power, 170.

The author, after explaining why it was impossible to adopt either the paddle-wheel or the screw as a means of propulsion, gave the following reasons in favour of the hydraulic system, adding that the actual trials have fully justified its adoption.

1. The propelling power is instantaneous, and as efficient in a heavy sea as in smooth water.

2. No racing, loss of power, or injurious effects to the machinery in a rough sea.

3. No vibration such as is caused by a screw or paddle-wheel.

4. The engine only running in one direction, there is no excessive wear of machinery, or loss of time due to stoppage and reversal.

5. The management of the vessel is in the hands of the officer on deck.

6. No obstacles under water to interfere with sailing.

7. When the rudder is damaged, steering can be effected by the turbine.

The vessel is divided into 15 water-tight compartments and possesses exceptional stability, righting herself up to an angle of 110°, and on trial the manœuvring power was not less satisfactory. A number of interesting experiments which had been made with a view to ascertain the behaviour of the boat in the presence of wreckage were also described; their results were all that could be desired.

The propelling machinery has been constructed by Messrs. Thorneycroft, of Chiswick, the engines being of the horizontal compound surface-condensing type, with cylinders $8\frac{1}{2}$ in. × $14\frac{1}{2}$ in., and 12 in. stroke. The paper gave details of the boilers, fan engine, turbine, &c., and it may be added that this turbine delivers water through the outlets at the rate of 1 ton per second; the sailing power is good.

The well accommodates 30 passengers and is abaft the machinery. Under its deck are two water-tanks, which are filled when leaving for a wreck, being emptied when passengers are taken on board.

The consumption of coal, even under forced draught, is small, averaging 2 cwt. per hour, so that the bunkers hold a sufficient supply for 30 hours.

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2. *On Aluminium Bronze for Artillery and Small Arms.* *By* J. H. J. Dagger, *F.C.S., F.I.C.*

As early as 1859–60, guns were cast in aluminium bronze by the French and Bavarian Governments, and favourably reported upon by the authorities; but the high price of aluminium at that time prevented its use for guns.

The cost of aluminium bronze in 1860 was 4*s.* 11*d.* per lb.; to-day it is on the market at 1*s.* 4*d.* per lb.

The results of mechanical and physical tests point to the fitness of this alloy for artillery and small arms under the altered condition of explosives, the recent trials of artillery—using the smokeless powder—by the German authorities proving that steel guns were seriously injured by the new ammunition, and a return to bronze for guns is advocated by their artillerists; but in the properties essential to good gun-metal, aluminium bronze surpasses the 'steel bronze' or the tin bronze used in the Uchatius system of gun fabrication. The following table gives comparative tests of this alloy and aluminium bronze:—

Alloy	Tensile strength in lbs. per sq. inch	Elastic limit pounds per sq. inch	Elastic extension per unit length	Ultimate elongation per cent.	Reduction of area per cent.	Hardness
Steel bronze (Sn 8· Cu 92·) cast in chilled mould	43,200	5,672	0·0004	40	—	5·
Steel bronze from bore of gun (mandrelled).	60,350	15,620	0·00306	16·5	44	20· (?)
No. 3 Al. bronze: Al. 7·5, Si 0·75, Cu 91·75, cast in chilled mould	69,800	21,500	0·00133	32·8	32·1	13·46
No. 1 Al. bronze: Al. 10· Si 1·0 Cu 89·	114,514	—	—	0·45	—	—
U.S. Ordnance .	109,823	79,894	—	0·05	—	21·17
Office tests . .	111,400	84,000 probable	—	6·50	—	—
Gun steel . .	98,134	57,796	—	16·	—	—
Compression test of No. 1 Al. bronze at Watertown Arsenal, 160,400 lbs.						

Tests have shown that aluminium bronze maintains its strength through a high range of temperature, being heated up to 500° F. without injury to its strength. No liquation or separation of the metals takes place, as is the case with tin bronze; neither does it alter in composition or quality even after repeated remeltings, and so obsolete and unserviceable guns would still retain their value as scrap metal, and could readily be utilised for new ordnance. Its low melting point—1,600° to 1,700° F.—would be favourable to good results, using the Rodman method of cooling the casting from the inside.

Its resistance to corrosion, its non-liability to crystallise under repeated shocks, as shown by a needle in a Springfield rifle bearing 11,000 discharges without being injured, would make it valuable for rifles and small arms. These alloys, having a tensile strength of 114,000 to 72,000 lbs. per sq. inch, and elongation from nil to 40 per cent., and elastic limit from 20,000 to 80,000 lbs. per sq. inch, values likely to be increased by a process similar to those of Dean or Uchatius, would give us a gun which would probably stand the severest test service.

The cost of a finished gun (at the present price of aluminium and copper) would be about 196*l.* per ton.

These new alloys would enable us to provide rapidly in any emergency the artillery and armament necessary for the public service.

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3. *Some new Telemeters or Range Finders. By* Professors A. BARR *and* W. STROUD.—See Reports, p. 499.

FRIDAY, SEPTEMBER 5.

The following Reports and Papers were read:—

1. *Report of the Estuaries Committee.*—See Reports, p. 512.

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2. *Report of the Graphic Methods Committee.*

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3. *The Process of Manufacturing Netting by slitting and expanded Sheet Metal. By* J. F. GOLDING.

Expanded metal is an article so dissimilar to other manufactures of metals as to require an arbitrary name, and the one given it is but meagrely suggestive of the process involved in its production, and not of its qualities or appearance, as these are only understood by the fullest description, or by ocular or physical demonstrations and tests; but the name, suggesting the expansion of metal, does serve to excite attention to the fact that thereby some new product of metals has been made.

Briefly stated, the process of making expanded metal is the employment of a machine, which so operates on a sheet or strip of metal as to slash it at intervals in parallel lines, so as to leave uncut spaces, which serve to maintain the connection between all the strands produced by the act of slashing. The method by which this slashing, as well as the opening up of the sheet or strip into meshes, is performed is peculiar, and one which makes it possible to transform the sheet or strip of metal into a finished article at one operation, and to this achievement is due the great commercial value of the invention. The simultaneous act of slashing and opening or expanding the sheet or strip at the slashes, leaving uncut spaces, and giving uniform design and set to the metal forming the meshes, is exceedingly novel, and most difficult of explanation, except by witnessing the movements of the machines.

These machines are necessarily heavy to secure rigidity and consequent accuracy in the slashing and shearing of the metal, but they are at once recognised to be very compact and simple.

Any homogeneous metal, such as steel, copper, brass, &c., can be employed. The machines as now constructed automatically feed a strip of steel between their cutters, which, as explained, simultaneously slash and expand the metal into meshes. These strips may be of any width, from 1 to 8 inches or wider, according to the design of the machine or width of expanded metal desired; the ratio of expansion being determined by the size of the mesh. Thus, a strip of steel 7 inches wide by 9 feet long, made into $\frac{3}{8}$-inch mesh for lathing, gives as a result a sheet of finished product, 18 inches wide and about 5 per cent. shorter than the original strip, whereas a strip of metal 6 inches wide and 9 feet long, made into a 4-inch mesh for fencing, gives as a result a finished sheet 4 feet wide by 8 feet long.

The cut edges of the strands forming the meshes are presented to the surface in the finished sheet, thus giving rigidity to the expanded sheet many times greater than the original flat sheet or strip.

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4. *Cable Tramways.* *By* W. NEWBY COLAM.

The author considered the present to be a not inopportune year for bringing before the British Association the subject of his paper, because the conditions imposed on the public had so changed of late as to make it necessary to adopt some system of locomotion whereby citizens can be carried at cheaper rates and more quickly than by the plodding horse.

The various means of utilising electricity, air, steam, gas, and ammonia for street traction were briefly referred to, and the author considered that only two of them that had been working a sufficient time to afford a commercial test had been able to survive. These were the cable and steam as applied to locomotives. Of the electrical motors undergoing commercial trials abroad, he was of the opinion that the storage system was the only one likely to be seriously entertained in this country for street purposes. The author hoped that the day would not be far distant when it could be proved that this means of applying electrical locomotion in streets could be worked at a fair remuneration over the average roads, because he considered it would then have a big field of operation. He, however, had formed the opinion that electrical engineers had many difficulties to surmount before this class of motor could face the varied work of ordinary streets and pay well in this country. Steam-engines were, in his opinion, not likely to receive much attention in the future for the purposes of traction through streets; but he thought they would be found to be useful means of connecting districts. Under the circumstances he suggested that in the cable might be found the mechanical power to supersede horses in cases where horses were clearly not capable of meeting the new conditions of travel.

The author next described the origin of cable tramways. He said success had attended almost every inauguration in America and elsewhere, notwithstanding quite unnecessarily large capital outlays. There are at present 501 miles of cable tramways at work, which carried last year over 794,000,000 of people, or nearly double the total passengers carried in England, Wales, Scotland, and Ireland. Dividends of 74 per cent. have been earned by the cable abroad, and in England they are now being worked at 47 per cent. of the gross receipts. The author gave his opinions as to the requirements to be observed in designing cable tramways in order that they may meet with the approval of local authorities and ensure economical results. He then described two lines he had made in Edinburgh which have 5·4 miles of track worked from one depôt, 3 miles of which are in one district and 2·4 in quite another part of the city. The total cost of construction and equipment to meet a three-minutes' service of cars was stated to have been 57,230*l.*, which was little more than for a horse-tramway to meet the same traffic. He predicted that such a low constructional and equipment cost for a system working at 47 per cent. in this country could not fail to attract attention and demand the consideration of tramway authorities.

The paper was illustrated with models and diagrams.

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5. *On the 'Serve' Tube.* *By* W. BAYLEY MARSHALL, *M.Inst.C.E.*

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6. *The Simplex Brake.* *By* W. BAYLEY MARSHALL, *M.Inst.C.E.*

The principal feature of this brake is that it can be applied or released from either side of the wagon; it is thus equivalent to an ordinary lever brake upon each side of the wagon, but with this important difference, that in the case of the ordinary lever-brake it must be released or taken off on the *same side* on which it was applied or put on; the Simplex can be taken off or put on at either side.

The brake apparatus consists of a lever or actuating handle, pivoted at its centre, and working horizontally under the wagon. This lever is furnished with a toothed rack to hold it in any desired position, and is connected by two links or pull-rods to the ordinary brake apparatus. These links are furnished with slots, which engage with suitable pins upon the lever which they are connected to, and equidistant from the central pivot. The normal position of the lever is at right-angles to the side of the wagon; if the end be either pulled towards or pushed from the headstock the brake is applied by means of the slotted pull-rods, the lever acting in the first or second order according to the direction in which it is moved. The action is the same upon both sides of the wagon.

This brake has been working for some time past with great success upon the London and South-Western, North-Eastern, Great Eastern, and Belfast and Northern Counties Railways. It can be applied to present vehicles at small cost, as the brake-rigging, such as shafts, hangers, levers, and brake-blocks, can be utilised.

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7. *A Rotary Machine for Composing and Distributing Printing Type.* *By* JOHN SOUTHWARD.

The author described an apparatus known as the Thorne Combined Type Setting and Distributing Machine, one of the main features of which is that the rotary principle has been utilised in it with remarkable results. In previous inventions for the same purpose there has usually been an apparatus for distributing and one for setting the type. It has not been found practicable to construct a distributor which will do the work quicker than it is done by hand, and in some cases the saving obtained from the mechanical composer is almost entirely lost by the slowness of the distribution. Hence the failure of nearly all the composing-machines hitherto invented.

The two principal features of the new Thorne apparatus are a keyboard and two vertical cylinders having the same axis, the upper cylinder resting upon a pillar on the lower one. Both cylinders are cut with a number of vertical grooves of such a form as to receive the type which is to be first distributed and then reset. There are ninety of these vertical grooves in each of the cylinders, sufficient to contain all characters and kinds of characters that are wanted for ordinary purposes. The keyboard carries a number of keys corresponding to that of the grooves, and when the machine is in operation, whatever key is depressed the letter corresponding to it is ejected from its proper groove in the lower cylinder upon a circular and revolving table, which has the same axis as the cylinder but is of larger diameter. Quite a number of types may thus be ejected from the grooves in each revolution of the disc, and all are brought round in their proper order to a point of delivery, where they are conveyed by a travelling band and fed continuously to a setting stick in front of the keyboard and thence to a galley. Here, any 'justifying' that may be necessary is done by a second operator, who sits opposite a small case containing spaces, quads, and so forth.

The control of the types is effected by forming on the side of each character recesses, something like the wards of a key, the arrangement, of course, being different for each different character. The grooves in the lower cylinder are provided with projections corresponding to these grooves on the types, so that no type will fall into any groove other than that for which it is intended. This arrangement applies only to the lower cylinder, which does not revolve. The grooves in the upper or distributing cylinder are large enough to receive all the types indifferently that are fed into them. The work of distribution is effected as follows: A suitable attachment to the side of the upper cylinder enables the operator to place the galley containing the type to be distributed in contact with the cylinder, and by a simple device line after line of type is fed into the cylinder until, if desired, every groove is nearly filled, and the upper cylinder is caused to revolve upon the lower one, with which it is in contact. As the columns of mixed type pass over the bends of the shaped grooves of the lower cylinder, letter by letter falls into its proper groove as soon as the nicks in the types find their corresponding wards. In this way, and at a speed depending on the rate at which the revolving table is driven, the types are all under perfect control of the compositor.

By the adoption of this rotary principle the usual speed of a composing-machine has been enormously accelerated. It has been found possible to compose with accuracy over 12,000 types per hour—the usual speed at which manual composition is done being about 1,000. The distributing is, of course, done at the same rate of 12,000 per hour; indeed, the rate is practically unlimited. The distributing is done with greater accuracy than in the ordinary way by hand, as no type can get into a wrong cylinder. From the extraordinary results obtained during the last few months, it may be expected that in future the rotary principle will supersede all present appliances which depend upon a guide plate, with its channels and switches so easily deranged, and working at such a comparatively low speed, just as in printing machinery the cylinder has superseded the platen of the press.

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8. *The Victoria and other Torpedoes. By* G. Read Murphy.

The torpedo, by which term is meant a mass of explosives used for any destructive purpose, has been known and used since explosives were discovered and their power realised.

The first successful torpedo that is recorded was used by Zambelli, an Italian engineer, in 1585, at Antwerp. He completely destroyed a bridge with the aid of a very primitive boat-torpedo. Since then, up to within comparatively recent periods, torpedoes have been used, though with very poor results. In fact, with the exception of one case, where it is claimed that a Whitehead torpedo sank a vessel in the Russo-Turkish war, the spar torpedo has been the only torpedo that has damaged or destroyed a vessel.

The torpedoes now in use are the Whitehead torpedo—with which is included the Schwartzkoff torpedo, which is simply a Whitehead torpedo made of phosphor bronze; the Brennan torpedo, which has established a reputation in England; the Simms-Edison, and the Patrick torpedoes, which have established reputations in America; and the Howel torpedo, which has received the favourable notice of experts of many nations; and, lastly, the Victoria torpedo.

The Whitehead torpedo, which is in reality the father of modern torpedoes, was originated by the Luppis surface torpedo-boat. In 1864 Mr. Luppis and Mr. Robert Whitehead, then managers of small ironworks at Fumay, entered into an agreement to develop this torpedo. The results of their experiments and labours have been that they now have a torpedo 20 feet long by 18 inches in diameter, which is stated to have attained a speed of 33 knots per hour for a distance of 1,100 yards, running under water at a given depth. These torpedoes—or rather torpedoes of which the present is a very great improvement—have been used in many wars, notwithstanding which they have, with the one exception above named, failed to do any damage. That they have thus failed is attributable to the fact that the users made the mistake of pointing them at the object they were to hit. It will be thus seen that uncontrolled torpedoes, except for very short distances, are very unreliable weapons; and though for short distances the Whitehead torpedo, or modifications of it, may never be excelled, still, for general purposes, it is an admitted fact that only a controlled torpedo will be effective. With this fact in view, Mr. Brennan, of Melbourne, conceived the very ingenious idea of making a torpedo to go in a similar manner to a cotton-reel if you put it on the floor and pull the cotton. This torpedo claims to have a range of 3,000 yards from a given position. Even supposing it to have this range, as the given position will be known to every Power of importance it will never be a very formidable weapon.

The Simms-Edison is a torpedo worked by electricity generated at the sending station, and thus has the same disadvantage that the Brennan torpedo has—viz., that it can be only worked from a fixed point that will be known by all Powers of importance. They, both of them, are in fact torpedoes tied by the tail to a stationary position.

The Patrick torpedo is a torpedo whose motive power is carbonic acid gas; this torpedo can be used from any station, and it has been under the notice of experts for a great number of years, but has failed to earn their approval.

The Howel torpedo is worked by power from a fly-wheel which is revolved at a rate of 4,000 revolutions per minute. This torpedo compares favourably with the Whitehead for going short distances, for, though it is so slow, it keeps a straight course.

The last torpedo is one of the author's invention, which has so far been fortunate in receiving the approval of all the leading experts, none of whom has yet been able to point out any weakness in its mode of operation. This torpedo is similar to a Whitehead torpedo, containing many improvements, and under perfect control. It can be used from any position, either on shipboard or on land, and can, with all its appliances, be taken about in a couple of wagons.

The idea of controlling a torpedo by electricity is not at all new. The author was informed by Mr. Anderson, who was lately in the employ of the English Government, and on the Torpedo Board of the Admiralty, that nine years ago he made a Whitehead torpedo to be steered by electricity direct, but it failed to meet with the approval of the authorities. Many other inventors have brought out various plans for steering torpedoes with electricity direct, but as electricity transmitted along a thread wire for the necessary distances is a weak and virtually ungaugable power, they have not succeeded. In the Victoria torpedo, by the use of springs (one of which was exhibited), this difficulty has been overcome, as all the electrical power has to do is to tap a spring which, by working a ratchet-wheel, controls and governs the torpedo. By these means you have a power on any required strength arrived at by simply using stronger or weaker springs, and this power is transmitted as required by the use of the ratchet-wheel, so that the torpedo is in every way controlled by a thread cable.

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9. *The Bénier Hot-Air Engine or Motor.* *By* E. Vernon.

The question of hot-air or caloric engines has greatly interested the scientific and engineering world for many years. It has been generally admitted that the discovery of a really good hot-air engine would be of the greatest importance from economical and other considerations; amongst other advantages, boilers, with their attending expense and danger, being entirely dispensed with.

The author exhibited sectional diagrams of the hot-air motor invented by MM. Bénier Frères, and manufactured by the Compagnie Française des Moteurs à Air Chaud of Paris. Several hundreds of these machines are already in use in France, Germany, and Belgium for electric lighting and other purposes, and a number of them have been supplied to the French Government for use in the most important lighthouses on the coast (Belle Isle, Dunkirk, &c.). In the engine described the air passes through the fire itself directly into the combustion chamber. With this type of engine a much greater initial pressure can be obtained than in engines using a separate combustion chamber, where the air is heated through an intervening metallic diaphragm. The drawing up of the grit and ashes is completely prevented in the present motor, this latter feature forming an important part of the invention.

As was seen by the diagrams, the engine is constructed on the beam principle, and the combustion chamber is really a prolongation of the working cylinder. The piston, or, more properly speaking, plunger, is of considerable length, the upper part only being made to fit the cylinder; the lower part of the plunger is of slightly less diameter, consequently an annular space is formed between it and the cylinder.

This space is connected with the main air supply, which is controlled by a valve, operated by a connecting-rod and cam lever worked from a cam on the crank shaft of the engine. The air-pump is placed in the centre of the machine, immediately beneath the beam standard, and is operated by a rod attached to the rocking beam, and this is connected by a rod to the crank shaft.

Owing to the position of the beam, pump, and connecting-rods, the piston of the air-pump is at the outer end of its stroke when the working piston on its return stroke has reached a middle position. During the last half of the return stroke of the working piston the air-piston is pushed inwards and compresses the charge of air previously drawn in until it has reached the middle of its stroke, at which moment the working piston is at the end of its stroke. The air-valve operated by the cam, as already mentioned, has communicating passages with the air-pump, the furnace or combustion chamber, and the annular air or packing space in the main cylinder. Consequently the compressed air is forced partly through the fire and combustion chamber, and partly into the annular air space, the flow of air continuing during the time the air-piston performs the second half of the stroke. Meantime the main piston receives its charge from the combustion chamber, and cold compressed air passes into the annular space and practically acts as a packing, effectually preventing grit and dust rising from the fire to the working faces of the cylinder. When the air-pump has finished its stroke, the air-valve is closed, and the air in the working cylinder is allowed to expand for the remainder of the stroke. The cylinder is kept cool by means of a circulating water-jacket. The bottom of the combustion chamber is hinged and lined with plumbago, and the fuel used is coke. As the combustion takes place under pressure, an automatically working air-lock is employed for feeding the fire.

The consumption of coke is from about $1\frac{1}{2}$ lbs. to $2\frac{1}{2}$ lbs. per h.p. per hour. These engines have now been working on the Continent for some time with extremely satisfactory results, and one can be seen at the premises of Messrs. Powis, Bale, & Co., Engineers, Appold Street, Finsbury, E.C.

SATURDAY, SEPTEMBER 6.

The following Papers were read:—

1. *On the Pneumatic Distribution of Power. By* Professor A. Lupton.

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2. *On the Construction of Sluices for Rivers, &c.* *By* F. G. M. Stoney, *M.Inst.C.E.*

In Indian irrigation many attempts have been made to work, or render more workable, sluices for the supply of water to canals, and while some experimenters confined their attention to finding means of overcoming great resistance with greater power, others have more properly sought to devise means for eliminating resistance to motion in sluices, rather than overcoming that resistance. This latter is the true direction to work in, and has eventually conduced to the best results.

Several forms of the throttle valve have been tried on irrigation sluices, and have not succeeded. This principle is not very suitable for substances like water, because what may be nicely balanced in static pressure may not be at all balanced when eddies and reflex forces are generated under high velocities. Such sluices have also failed mechanically, because of the too great concentration of load on pivots; moreover these pivots may be subject to the action of rust and grit.

The ordinary sliding doors are subject to an amount of friction which precludes their useful application to such large openings as are now generally required.

Equilibrium sluices have been made by arranging two outlets directly opposite each other, and the two doors closing the outlets so constructed as to form one plug (as it were) filling the space. The water pressure on one door being equal and opposite to that on the other door, the pair were in equilibrium. Here again was a very promising scheme, but the heavy bodies of water directly impinging would quite prevent this appliance being used in great sizes.

Another form of equilibrium sluice, specially designed for canal locks, was made by stopping a horizontal circular orifice by a cylinder. This cylinder had neither top nor bottom. Its lower edge, neatly faced in the lathe, rested on a suitably prepared face round the valve seat, and the top of the cylinder stood above water level. In this way the column of water was completely removed from above the sluice orifice, and the surrounding water simply tended to compress the cylinder, but not to prevent its vertical motion. The weight of the cylinder was balanced, and lifting it one-fourth of its diameter gave the full area of the sluice way.

Many of these sluices were made, and proved very useful. They were abandoned by the author chiefly for two faults: they pumped large quantities of air into the culverts, and they could not be applied to direct openings for scouring purposes.

The most successful sluice for almost any situation is the sluice on free rollers. In this case there is not any sliding friction. The sluice door had its load of water pressure on free rollers, the motion being similar to that of draw-bridges on free rollers, and to that of observatory cupolas mounted in a like manner. There is, however, one marked difference as to the planes of motion. The ordinary application of free rollers is on horizontal planes; in the sluices it is on vertical planes, which was one of the primary difficulties in the way. But no doubt the bare idea of introducing free rollers between the sluice door and the sluice frame, apparently precluding the possibility of a water-tight joint, was the real stumbling-block to be got over.

Sluices on free rollers are now constructed to any required size, and to be easily workable under great pressure by one man, without hydraulic power. They have proved very reliable during years of test, and the wear and tear is hardly noticeable, chiefly because of the absence of resistance.

These sluices are made to suit single, double, or alternate pressures, and they are made water-tight in various ways, according to the degree required, from absolutely tight sluices to sluices purposely not made tight.

These sluices can be usefully applied to the purposes of increasing water power without increased risk of flooding the country; on the contrary, they have proved most successful in preventing floods.

They can also be applied to the main stream of navigable rivers, as in the plan now sanctioned by Parliament for Richmond, in which three sluice gates, each 70 feet clear span, are used to hold up water to half-tide, and at that period or level of water the gates are quickly raised some 23 feet above Trinity high-water mark, to allow of barges and steamers sailing under.

A new element has been introduced into these sluices, by which, during the upper part of the lifting process, the gates automatically turn over on their flats and disappear in the overhead bridges.

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3. *The Raiyān Canal.*[1] *By* Cope Whitehouse.

The general character of this canal, which it is intended to construct between the Valley of the Nile and the Raiyān depression, at a point about 80 miles south of Cairo, was explained at the Bath meeting. The proposed works have now been elaborated in detail: (1) the size of the basin; (2) the section of the canal; (3) the water-surface levels of the Nile; (4) the minimum level of the Nile in flood; (5) the works to the west of the Nile Valley—excavations, earthworks, pitching, and masonry; (6) the works in the Nile Valley for the passage of existing canals, drains, and railways under and over the Raiyān flood-canal; (7) the time required to fill the reservoir; (8) the quality of the water stored: tables, maps, sections, photographs exhibited, and estimates given.

With an 80-metre wide canal the flood could be lowered at 50 centimetres per 24 hours, and the reservoir, 250 square miles in area, and 220 feet in maximum depth, filled to the level of + 27 metres above sea in three years. The total cost is estimated at less than 1,589,000*l*. The duty of the reservoir would be to raise the minimum flow of low-Nile from about 9,000 feet per second to 30,000, and fix a maximum for high-Nile. The results anticipated would be practically to double the present cultivated area and agricultural output, with large extension of internal navigation in the Delta.

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[1] Published in *Engineering*, September 19, 1890.

MONDAY, SEPTEMBER 8.

The following Papers were read:—

1. *A New Electric Meter. The Multicellular Voltmeter. An Engine-room Voltmeter. An Ampère Gauge. A new Form of Voltapile, useful in Standardising Operations. By* Sir WILLIAM THOMSON, *D.C.L., LL.D., F.R.S.*

2. *The Lineff Electric Tramway. By* GISBERT KAPP.

The conductor consists of bare copper strip or cable and of iron strip. The latter is galvanised so as to protect it from rusting. It lies on the copper conductor, and both are enclosed in a sealed channel formed of asphalt. The copper conductor rests upon the bottom of a trough made of a succession of glazed tiles, and the cover to this trough is formed by the lower flanges of iron rails arranged in short sections so as to be insulated from each other. The head of one rail reaches up to the surface of the road, the head of the other is cut off, and this rail is therefore completely buried in the asphalt. The surface rail, which may be arranged alongside one of the ordinary tram rails or in the centre of the track, is in electric and magnetic contact with an electro-magnet carried under the car. This magnet runs upon the surface rail on wheels which form its north and south poles. The distance of the wheels is greater than the length of a section of insulated rail, so that successive sections become oppositely magnetised. This causes the iron strip immediately below the magnetised region to be attracted upwards and thus come into contact for a length of several feet with the under side of the two sectional rails. At the same time the iron strip to both sides of this region remains in contact with the copper conductor and forms thus an electrical connecting link between the copper conductor and a few sections of insulated rail under the car. The current passes from the surface rail through the body of the electro-magnet (which is insulated from the body of the car) into the motor, and finally into the ordinary tram rails and earth in the usual manner. The electro-magnet is energised by a shunt current obtained from the main conductor, but to provide for the possibility of dropping the strip from some unforeseen cause there is placed on the electro-magnet a third thick wire coil, which can at all times be energised by two storage cells carried on the car, and thus the strip can be picked up and the main circuit again established if it should have been accidentally interrupted. It may, however, at once be stated that during some tests made on an experimental line of this kind, and which lasted over several days, there has been no need for the picking-up battery, as the current was never lost. The way in which Mr. Lineff makes use of magnetic lines of force to effect the attraction of the iron strip deserves attention. It might perhaps be thought that the most direct, and therefore the best, way of utilising the lines of force would be by one single line of sectional rail, through which there would be longitudinal magnetic flux corresponding with the fore and aft position of the poles, and attraction of the strip at every gap between two sections. Experiment has, however, shown that this apparently direct way is by no means the best way, and that far more satisfactory results can be obtained by arranging a more roundabout course for the lines of force. This is attained by the employment of the subsidiary or buried rail, the gaps in which do not exactly correspond with those in the main or surface rail, but are shifted forward by a certain amount. In consequence of this arrangement the buried rail acts as a kind of magnetic bridge to successive portions of the surface rail, and this action takes place in two ways, one direct and the other indirect. The direct way is longitudinal and does not affect the strip at all. The indirect way is both longitudinal and transverse, the latter passing several times through the strip. The buried rail is a rather imperfect bridge to the lines of force traversing it longitudinally, because its magnetic resistance in that direction is great, but this rail forms a very efficient bridge for lines passing through it transversely, owing to its lower magnetic resistance in that direction which includes the strip. The flow of magnetic force transversely is therefore that which effects the attraction of the strip, and may be represented as a series of magnetic stitches passing to and fro between the two sets of rails and the strip.

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3. *Alternating* versus *Continuous Currents in relation to the Human Body. By* H. Newman Lawrence, *M.I.E.E., and* Arthur Harries, *M.D.*

This paper is based upon experiments made with dynamo-generated currents, both continuous and alternating, and with the skin of the subjects in its normal, unmoistened state. The matter is considered under the following heads, viz.:— Resistance, including variations due to change in contact-area; and Sensations, including initial shock and continued contact.

Resistance was measured by connecting two or more persons to a dynamo circuit at an E.M.F. of about 100 volts, noting the current-strength passed, and then calculating therefrom the resultant resistance of each person. The tables given show an average resistance to continuous current of 6,185 Ohms, and to alternating current of 4,008 Ohms—*i.e.*, about 1·5 higher for continuous current than for alternating. Experiments made regarding contact-area showed that it is an important factor 'in determining the seriousness or slightness of accidents in light and power circuits.'

Sensation was tested by passing currents from the same dynamos, using resistance-coils to reduce the current to a convenient level. Two distinct points of comparison were taken, one called 'Discomfort Point,' and the other 'Fixation Point.' The tabulated results show that discomfort point was reached with an average of 18·7 milliampères of continuous current, and with 3·9 milliampères of alternating current. This indicates that sensation to alternating current is 4·7 times greater than it is to continuous current.

With continuous current, 'in each instance burning sensation under the electrodes became unbearable after about thirty seconds; this was the only objectionable feature, though electrolytic action was sufficiently marked to induce slight blistering in two of the cases.'

With alternating currents, a tingling sensation was felt, rapidly increasing to muscular contraction, becoming more and more unpleasant, and accompanied by a feeling of heat in the neighbourhood of the electrodes, though not immediately under the site of contact, as in the case of the continuous current.

The average fixation point to alternating current was 7·5 milliampères; but *no such point could be found with the continuous current*, thus emphasising this important difference between the two forms of current as regards danger likely to result from accidental contact.

Initial shock is defined as that in which the time-period of contact was a minimum. Many subjects were tested, who one and all considered the initial shock of continuous current to be far less unpleasant than that of alternating current when equal current-strength was used; but 'this, from the nature of the experiment, can only be tested with small currents, and it is conceivable that with larger currents such marked differences may not be observable.'

In continued contact with the continuous current 'we have no muscular fixation, and the subject of the accident would be able to release himself.' On the other hand, with alternating current 'the subject would be absolutely fixed *in situ* until released by extraneous aid, being exposed the whole time to the full effect of the current passing.'

In drawing the following conclusions, the authors say: 'We desire to call attention to the fact that they are based upon certain conditions, and, while we believe them to be sufficiently accurate and reliable under these conditions, we in no sense claim them as true under all conditions.'

'Conclusions.

'(*a.*) That when the human body, with the skin in its normal, unmoistened condition, comes into contact for an appreciable time with bare-metal conductors of a dynamo-generated continuous current passing at about 100 volts, in such a way that the current passes from hand to hand, and the total contact-area is about 90 square centimètres:—

'1. A current of about 0·016 Ampère will pass through it.
'2. That this current can be borne without discomfort for fifteen to thirty seconds.
'3. That after about thirty seconds unpleasant burning sensations become marked, and quickly increase.
'4. That the subject is perfectly able to release himself at will during any portion of the time of contact.

'(*b.*) That when the human body comes into contact with dynamo-generated alternating currents alternating at about sixty to seventy per second, under the same conditions as above:—

'1. A current of about 0·025 Ampère will pass through it.
'2. That this current is *six times greater* than that which produces discomfort.
'3. That instantly the subject is fixed by violent muscular contraction, and suffers great pain.
'4. That the subject is utterly unable to release himself, but remains exposed to the full rigour of the whole current that may be passing.

'(*c.*) That when circuit from electric-light or power conductors is accidentally completed through the human body, the *danger of serious consequences is many times greater when alternating than when continuous currents are passing* at equal voltage; and this is still, to a large extent, true if the voltage of the continuous current be double that of the alternating.

'(*d.*) That with both forms of current a reduction of contact-area materially reduces the amount of current-strength that passes.

'That with the alternating current, if the rate of alternation be reduced below fifty per second, the sensations of pain accompanying muscular fixation will be increased; while, if the rate of alternation be increased, the pain will be diminished.'

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4. *On Electric Lighting and Fire Insurance Rules.* *By* WILSON HARTNELL.

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5. *Secondary Cells.* *By* W. J. S. BARBER STARKEY.

The author in this paper limited himself to a description of his own experiences in regard to secondary cells, primarily with a view to provoke discussion on the subject.

Soon after the introduction of M. Faure's cells his attention was drawn to the hard film of sulphate of lead formed on the plates which materially interfered with their efficiency, and, as a result of experiments, he ascertained that the addition of a small quantity of carbonate of soda to the dilute acid serves to remedy this evil, even when the cells are allowed to remain idle for a considerable time. Subsequently, in the case of a small installation of twenty-two E.P.S., 350 Ampère-hour cells, the plates of which showed signs of sulphating, carbonate of soda (ordinary washing soda) was added in small quantities, and on proceeding with the charging the plates were restored to their original condition. The cells thus treated have since been in use for a period of five years, and are now in perfect condition. The subsequent experiments on this subject by Mr. Preece were alluded to.

The author advised that large cells be used for stationary work, and that they be both charged and discharged at low rates. Various details in regard to the management of cells were discussed, the practice of packing the plates in a solid though porous mass formed by mixing plaster of Paris and sawdust being specially recommended.

The paper concluded with the expression of a hope that a thoroughly practical cell for traction purposes may be introduced—one which will stand rough usage and be free from the defects which characterise those at present in use.

TUESDAY, SEPTEMBER 9.

The following Papers were read:—

1. *On the Form of Submarine Cables for Long-distance Telephony.* *By* W. H. PREECE, *F.R.S.*

The early possibility of talking by telephone between London and Paris has directed the author's attention to the proper form of cable to give the best result. There is a particular size of cable for every circuit, which will give the smallest possible outer diameter of gutta-percha at the least cost to secure clear speech. For the new Channel cable this comes out: weight of copper 160 lbs. and weight of gutta-percha 300 lbs. per nautical mile. The paper contains the mathematical development that leads to this conclusion.

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2. *Column-Printing Telegraph.* *By* F. HIGGINS.

This apparatus was originally patented ten years ago, and is now being practically introduced for the transmission of intelligence in this country.

The receiver, which is entirely automatic, consists of a type-wheel and frame carrying the paper-sheet. The former derives the motive power for its rotation from a train of wheelwork and a weight, and the latter from the battery at the sending end.

The type-wheel is displaced laterally, after each print, by means of a screw, and upon completion of a line of printing is released and returned to zero by a spring which has been wound up by the movement of the printing-lever.

One train of clockwork is employed, and the motive power for printing, feeding the paper, and traversing the type-wheel, is supplied by the printing electro-magnets.

About twenty of these instruments may be introduced into the circuit of a single line of wire, and any number may be worked from one transmitter. The type rotates at any desired speed (from 100 to 150 revolutions per minute), and the same signals operate both the type rotation and the printing, the difference being that the signals for printing are longer than those operating the escapement, in order to afford time for the establishment of the full strength of the current in the circuit, and to overcome the inertia of the comparatively heavy parts of the printing mechanism.

The other operations of synchronising, spacing between lines, &c., are determined by the angular displacement of the type-axis with respect to its zero position.

The transmitter is driven by an electro-motor, the speed of which is kept uniform by an electrical governor.

A counter upon the transmitter announces to the operator when a line of type has been filled.

From 1,800 to 2,000 words per hour would be the maximum speed.

Five thousand words can be received without attention, and the paper-supply is sufficient for the reception of 30,000 words.

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3. *On Heavy Lathes.* *By* A. GREENWOOD.

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4. *Factors of Safety.* *By* W. Bayley Marshall, *M.Inst.C.E.*

The factor of safety for materials used in constructional ironwork, bar iron of various sections and plates, whether the material is puddled or ingot iron, has usually been taken at 5 tons per square inch for ordinary quality and 6 tons for specially good material. This limit is based upon a total resistance of about 23 tons per square inch, and an assumed elastic limit of from 50 to 60 per cent. of the total stress.

The importance of considering the elastic limit in determining the factor of safety, or of ascertaining what stress any particular member will bear *before it begins to stretch,* has frequently been demonstrated.

In the tables appended to the present paper the writer has endeavoured to show that the elastic limit is the *only* constant quality in bar and plate iron; and that whilst the total stress is *frequently influenced by,* and the reduction of area and extension seem almost *absolutely to depend upon,* the shape of the specimen operated upon, yet the elastic limit remains constant, notwithstanding considerable variation in the dimensions of the specimens operated upon:—

No.	Description	Original Size of piece in feet	Original Area in feet	Tons per square inch		Reduction area per cent.	Stretch per cent.
				Elastic limit	Total stress		
1	$\frac{1}{4}$ plate	1·51 × 0·25	0·377	13·8	18·6	4·5	3
2	$\frac{5}{8}$ plate	2·02 × 0·61	1·232	13·7	22·7	10	11
3	6 × 6 × 1 angle	1·51 × 0·95	1·434	13·9	23·5	11	13
4	4 × $\frac{1}{2}$ bar	2·00 × 0·52	1·040	13·8	19·2	16	8
5	3 × 3 × $\frac{1}{2}$ bar	1·75 × 0·52	0·910	13·9	21·7	20	14
6	5 × $\frac{3}{4}$ bar	2·02 × 0·76	1·535	13·8	22·3	21	20
7	4$\frac{1}{2}$ × 4$\frac{1}{2}$ × $\frac{5}{8}$ angle	1·94 × 0·70	1·358	13·9	22·6	21	17
8	3$\frac{1}{2}$ × 3$\frac{1}{2}$ × $\frac{5}{8}$ angle	2·005 × 0·62	1·243	13·9	23·5	22	20
9	3$\frac{3}{4}$ × 1 bar	1·25 × 0·97	1·212	13·7	22·1	23	19
10	8 × 1 bar	1·505 × 1·02	1·535	13·5	22·7	23	22
11	3$\frac{1}{2}$ × 3 × $\frac{1}{2}$ angle	2·02 × 0·502	1·014	13·8	22·2	24	20
12	6 × 4 × $\frac{11}{16}$ tee	1·51 × 0·70	1·057	13·8	22·8	27	22
13	2$\frac{1}{2}$ × $\frac{3}{4}$ bar	2·51 × 0·76	1·907	13·6	21·7	30	29
14	2 × $\frac{1}{2}$ bar	2·02 × 0·51	1·030	13·7	21·5	32	26
15	6 × 5 girder	1·50 × 0·48	0·720	13·9	23·8	32	27
16	2$\frac{1}{4}$ round	1·29 dia.	1·307	13·5	23·0	36	28
17	1$\frac{1}{2}$ round	1·465 dia.	1·685	13·7	23·1	42	29
18	1 round	0·94 dia.	0·693	13·5	22·6	44	25
19	$\frac{3}{4}$ round	0·75 dia.	0·441	13·6	21·9	45	26
20	1$\frac{1}{8}$ round	1·13 dia.	1·000	13·7	22·7	55	29
21	$\frac{5}{8}$ plate	1·51 × 0·62	0·936	14·2	20·2	7	4
22	5 × 5 × $\frac{7}{8}$ angle	1·12 × 0·83	0·930	14·1	23·5	11	10
23	8 × 1 bar	1·01 × 0·97	0·980	14·4	22·7	11	16
24	7 × $\frac{3}{4}$ bar	1·27 × 0·75	0·953	14·4	21·4	16	10
25	6 × 5 × 1 angle	1·00 × 0·96	0·960	14·1	22·3	16	11
26	6$\frac{1}{2}$ × 4 × $\frac{9}{16}$ angle	2·01 × 0·54	1·085	14·0	23·4	17	13
27	6 × 5 girder	1·50 × 0·54	0·810	14·4	21·8	19	14
28	5 × $\frac{1}{2}$ bar	1·97 × 0·515	1·014	14·0	22·9	20	19
29	12 × $\frac{9}{16}$ bar	2·01 × 0·575	1·155	14·2	22·7	21	18
30	$\frac{5}{32}$ plate	2·01 × 0·15	0·302	14·1	34·5	23	13
31	2$\frac{1}{2}$ × $\frac{5}{8}$ bar	2·015 × 0·66	1·329	14·2	22·7	23	19
32	$\frac{3}{8}$ plate	1·885 × 0·40	0·754	14·0	22·9	25	21
33	2″ × $\frac{1}{2}$″ bar	2·00 × 0·54	1·080	14·2	22·3	25	23
34	4$\frac{1}{2}$ × 4$\frac{1}{2}$ × $\frac{5}{8}$ angle	1·48 × 0·60	0·888	14·1	22·0	28	20
35	$\frac{9}{16}$ plate	1·25 × 0·56	0·700	14·1	26·4	32	26
36	1$\frac{1}{2}$ round	1·26 dia.	1·247	14·4	23·6	38	28
37	2$\frac{1}{4}$ round	1·285 dia.	1·297	14·4	22·8	41	31
38	1″ round	1·04 dia.	0·849	14·1	22·8	48	26

No.	Description	Original Size of piece in feet	Original Area in feet	Tons per square inch: Elastic limit	Tons per square inch: Total stress	Reduction area per cent.	Stretch per cent.
39	$\frac{3}{4}$ round	0·745 dia.	0·435	14·4	23·5	51	25
40	$1\frac{1}{8}$ round	1·13 dia.	1·000	14·3	22·7	57	30
41	$\frac{5}{8}$ plate	2·02 × 0·62	1·252	14·9	18·1	2·3	2
42	$\frac{5}{8}$ plate	1·885 × 0·615	1·159	14·6	16·2	3	2
43	$\frac{1}{2}$ plate	2·00 × 0·505	1·010	14·7	18·3	4	3
44	6 × 5 × 1 angle	1·00 × 1·01	1·010	14·8	22·6	15	14
45	4 × 4 × $\frac{3}{4}$ angle	1·47 × 0·72	1·058	14·9	22·5	16	8
46	9 × $\frac{3}{4}$ bar	1·86 × 0·73	1·357	14·7	21·7	16	15
47	$\frac{3}{8}$ plate	1·77 × 0·39	0·690	14·5	23·3	17	11
48	4 × 4 × $\frac{3}{4}$ angle	1·13 × 0·75	0·848	14·6	23·7	21	17
49	5 × $2\frac{1}{2}$ × $\frac{3}{8}$ tee	1·83 × 0·39	0·714	14·8	21·6	22	13
50	$\frac{7}{8}$ square	0·88 × 0·876	0·770	14·9	24·2	27	21
51	$1\frac{1}{4}$ × $\frac{5}{8}$ bar	1·257 × 0·622	0·781	14·7	24·0	29	21
52	$\frac{3}{8}$ plate	1·51 × 0·40	0·604	14·5	30·3	30	20
53	$1\frac{5}{8}$ round	1·50 dia.	1·767	14·8	23·5	39	31
54	$\frac{1}{4}$ plate	1·76 × 0·27	0·476	14·7	33·4	39	20
55	1 round	1·02 dia.	0·817	14·8	24·2	40	28
56	$1\frac{1}{8}$ round	1·08 dia.	0·916	14·5	23·3	41	30
57	$\frac{3}{8}$ plate	1·76 × 0·39	0·686	14·6	30·1	42	26
58	$\frac{5}{32}$ plate	2·01 × 0·16	0·322	14·8	34·0	46	17
59	$\frac{3}{4}$ plate	1·50 × 0·76	1·140	14·9	27·2	54	28
60	$\frac{1}{4}$ plate	2·00 × 0·23	0·460	14·6	27·0	54	27
61	$\frac{9}{16}$ plate	2·02 × 0·587	1·185	15·3	18·0	6	3
62	$\frac{5}{8}$ plate	2·00 × 0·65	1·300	15·3	20·4	7	4
63	5 × 5 × $\frac{7}{8}$ angle	1·45 × 0·83	1·204	15·4	23·6	7	7
64	$\frac{5}{8}$ plate	1·90 × 0·60	1·140	15·0	19·8	8	6
65	$\frac{3}{4}$ plate	2·02 × 0·735	1·484	15·2	21·6	9	9
66	$\frac{1}{2}$ plate	2·00 × 0·48	0·960	15·1	21·6	14	8
67	6 × 1 bar	1·52 × 1·02	1·550	15·4	23·2	17	15
68	4 × 4 × $\frac{3}{4}$ angle	2·01 × 0·725	1·457	15·0	24·0	18	19
69	$\frac{5}{8}$ plate	1·89 × 0·605	1·143	15·3	23·1	19	17
70	$3\frac{1}{2}$ × $3\frac{1}{2}$ × $\frac{1}{2}$ angle	2·015 × 0·500	1·007	15·4	22·7	20	12
71	7 × $3\frac{1}{2}$ × $\frac{1}{2}$ tee	1·51 × 0·48	0·725	15·2	24·0	22	16
72	2 × $\frac{1}{2}$ bar	2·025 × 0·525	1·063	15·0	29·2	25	17
73	4 × 4 × $\frac{3}{4}$ angle	1·01 × 0·74	0·747	15·1	24·6	25	20
74	6 × 6 × 1 angle	1·505 × 0·928	1·396	15·3	24·4	26	22
75	6 × $\frac{1}{2}$ bar	1·10 × 0·48	0·528	15·1	23·8	35	25
76	$\frac{1}{10}$ sheet	1·75 × 0·090	0·158	15·2	38·0	41	9
77	$\frac{1}{4}$ plate	2·00 × 0·230	0·460	15·0	27·8	46	25
78	$\frac{3}{4}$ plate	1·50 × 0·76	1·140	15·4	26·4	54	29
79	$\frac{9}{16}$ plate	1·24 × 0·56	0·694	15·4	27·7	59	28
80	$\frac{7}{8}$ round	0·85 dia.	0·567	15·0	23·3	67	30
81	$\frac{5}{8}$ plate	1·52 × 0·62	0·942	15·6	20·7	4·5	6
82	$\frac{1}{2}$ plate	2·02 × 0·495	0·999	16·0	18·8	5	4
83	$\frac{5}{8}$ plate	1·38 × 0·60	0·828	15·9	23·6	11	10
84	$\frac{11}{16}$ plate	1·47 × 0·70	1·029	15·8	23·7	11	9
85	9 × 1 bar	1·00 × 0·97	0·970	15·9	22·9	12	10
86	6 × 6 × 1 angle	1·505 × 0·95	1·429	15·6	24·6	13	15
87	9 × $\frac{1}{4}$ bar	2·04 × 0·245	0·499	15·6	18·6	13	5
88	$\frac{1}{2}$ plate	2·02 × 0·50	1·010	15·5	22·6	15	12
89	5 × 5 × $\frac{1}{2}$ angle	2·01 × 0·505	1·015	15·7	24·2	18	15
90	6 × 3 × $\frac{1}{2}$ tee	1·52 × 0·50	0·760	15·8	24·9	21	20
91	12 × $\frac{1}{2}$ bar	1·99 × 0·49	0·975	15·5	22·5	22	17
92	$\frac{5}{32}$ plate	2·02 × 0·15	0·303	15·7	33·2	24	8
93	2 × $\frac{3}{4}$ bar	1·945 × 0·762	1·482	15·7	24·3	27	22
94	$1\frac{1}{16}$ round	1·065 dia.	0·890	15·8	23·0	46	32
95	6 × 1 bar	1·50 × 1·01	1·515	15·7	28·0	55	31

No.	Description	Original Size of piece in feet	Original Area in feet	Tons per square inch		Reduction area per cent.	Stretch per cent.
				Elastic limit	Total stress		
96	$\frac{3}{4}$ round . . .	0·75 dia.	0·441	15·8	24·6	56	26
97	$\frac{5}{8}$ plate . . .	1·00 × 0·63	0·630	16·0	27·9	58	29
98	$\frac{9}{16}$ round . . .	0·550 dia.	0·238	15·6	27·4	65	19
99	$\frac{7}{8}$ round . . .	0·850 dia.	0·567	15·9	24·9	69	29
100	$\frac{7}{8}$ round . . .	0·850 dia.	0·567	15·7	23·6	71	32

5. *Measurement of Elongation in Test Samples.* *By* J. H. WICKSTEED.

When a bar of metal is stretched with a longitudinal pull, it first extends generally throughout the whole of its free length; after which, especially in best iron, mild steel, and copper, it extends locally about the place of final fracture. The 'general' extension continues so long as the bar offers increasing resistance to the pull, and from the end of that stage to final fracture the extension is local.

The general extension is unaffected by the shape or proportions of the specimen, and may be correctly expressed in units of its own length.

The local extension bears no relation to the length of the specimen, and should, therefore, be expressed in standard units of length.

The usual engineering practice of the present day is to measure the total extension, and to express it in percentage of the original length of specimen; but this practice makes it difficult to draw correct comparisons of ductility between different experiments, unless the specimens have been all made to the same pattern. It also prevents the value of the material being discriminated as between capability for stricture and the capability for stretching without loss of strength.

The author describes a method for separating the measurement of the general extension from the local, and recommends a column in test reports of '% general extension,' leaving the present column of '% contraction of area' to record the capacity for stricture, and the present column of total extension in inches, from which the local extension can be deduced by subtracting the recorded general extension from the total as measured after the sample is broken.

6. *On the Measurement of Strains.* *By* A. MALLOCK.

7. *Exhibition of a Mechanism.* *By* Professors BARR *and* W. STROUD.

Section H.—ANTHROPOLOGY.

President of the Section—John Evans, D.C.L., LL.D., D.Sc., Treas.R.S., Pres.S.A., F.L.S.

THURSDAY, SEPTEMBER 4.

The following Address by the President was read by Mr. Rudler:—

In the year 1870 I had the honour of presiding over what was then the Department of Ethnology in the Biological Section of the British Association at its meeting in Liverpool. Since that time twenty years have elapsed, during the greater portion of which period the subjects in which we are principally interested have been discussed in a department of Anthropology forming part of the organisation of the Biological Section; although since 1883 there has been a new Section of the Association, that of Anthropology, which has thus been placed upon the same level as the various other sciences represented in this great parliament of knowledge. This gradual advance in its position among other branches of science proves, at all events, that, whatever may have been our actual increase in knowledge, Anthropology has gained and not lost in public estimation, and the interest in all that relates to the history, physical characteristics, and progress of the human race is even more lively and more universal than it was twenty years ago. During those years much study has been devoted to anthropological questions by able investigators, both in England and abroad; and there is at the present time hardly any civilised country in the world in which there has not been founded, under some form or another, an Anthropological Society, the publications of which are yearly adding a greater or less quota to our knowledge. The subjects embraced in these studies are too numerous and too vast for me to attempt even in a cursory manner to point out in what special departments the principal advances have been made, or to what extent views that were held as well established twenty years ago have had either to be modified in order to place them on a surer foundation, or have had to be absolutely abandoned. Nor could I undertake to enumerate all the new lines of investigation which the ingenuity of students has laid open, or the different ways in which investigations that at first sight might appear more curious than useful have eventually been found to have a direct bearing upon the ordinary affairs of human life, and their results to be susceptible of application towards the promotion of the public welfare. I may, however, in the short space of time to which an opening address ought to be confined, call your attention to one or two subjects, both theoretical and practical, which are still under discussion by anthropologists, and on which as yet no general agreement has been arrived at by those who have most completely gone into the questions involved.

One of these questions is—What is the antiquity of the human race, or rather what is the antiquity of the earliest objects hitherto found which can with safety be assigned to the handiwork of man? This question is susceptible of being entirely separated from any speculations as to the genetic descent of mankind; and even were it satisfactorily answered to-day, new facts might to-morrow come to light that would again throw the question entirely open. On any view of probabilities, it is in the highest degree unlikely that we shall ever discover the exact cradle of our race, or be able to point to any object as the first product of the industry and intelligence of man. We may, however, I think, hope that from time to time fresh discoveries may be made of objects of human art, under such circumstances and conditions that we may infer with certainty that at some given point in the world's history mankind existed, and in sufficient numbers for the relics that attest this existence to show a correspondence among themselves, even when discovered at remote distances from each other.

Thirty-one years ago, at the meeting of this Association at Aberdeen, when Sir Charles Lyell, in the Geological Section, called attention to the then recent discoveries of Palæolithic implements in the Valley of the Somme, his conclusions as to their antiquity were received with distrust by not a few of the geologists present. Five years afterwards, in 1864, when Sir Charles presided over the meeting of this Association at Bath, it was not without reason that he quoted the saying of the Irish orator, that 'they who are born to affluence cannot easily imagine how long a time it takes to get the chill of poverty out of one's bones.' Nor was he wrong in saying that 'we of the living generation, when called upon to make grants of thousands of years in order to explain the events of what is called the modern period, shrink naturally at first from making what seems so lavish an expenditure of past time. Throughout our early education we have been accustomed to such strict economy in all that relates to the chronology of the earth and its inhabitants in remote ages, so fettered have we been by old traditional beliefs, that even when our reason is convinced, and we are persuaded that we ought to make more liberal grants of time to the geologist, we feel how hard it is to get the chill of poverty out of our bones.'

And yet of late years how little have we heard of any scruples in accepting as a recognised geological fact that, both on the Continent of Europe and in these islands, which were then more closely connected with that continent, man existed during what is known as the Quaternary Period, and was a contemporary of the mammoth and hairy rhinoceros, and of other animals, several of which are either entirely or locally extinct. It is true that there are still some differences of opinion as to the exact relation in time of the beds of river gravel containing the relics of man and the Quaternary fauna to the period of great cold which is known as the Glacial Period. Some authors have regarded the gravels as pre-Glacial, some as Glacial, and some as post-Glacial; but, after all, this is more of a question of terms than of principle. All are agreed, for instance, that in the eastern counties of England implements are found in beds posterior to the invasion of cold conditions in that particular region, though there may be doubts as to how much later these conditions may have prevailed in other parts of this country. All, too, are agreed that since the deposit of the gravels considerable changes have taken place in the configuration of the surface of the country, and that the time necessary for such changes must have been very great, though those in whose bones the chill of poverty still clings are inclined to call in influences by which the time required for the erosion of the river valleys in which the gravels occur may be theoretically diminished.

On the other hand, there have been not a few who, feeling that the evidence of the existence of the human race has now been satisfactorily established for Quaternary times, and that there is no proof that what has been found in the ordinary gravels belongs to anything like the first phases of the family of man, have sought to establish his existence in far earlier Tertiary times. In the view that earlier relics of man than those found in the river gravels may eventually be discovered, most of those who have devoted special attention to the subject will, I think, concur. But such an extension of time can only be granted on conclusive evidence of its necessity; and before accepting the existence of Tertiary man the grounds on which his family-tree is based require to be most carefully examined.

Let me say a few words as to the principal instances on which the believer in Tertiary man relies. These may be classified under three heads:[1]—(1) the pre-

[1] See A. Arcelin, *L'homme tertiaire*, Paris, 20 rue de la Chaise, 1889.

sumed discovery of parts of the human skeleton; (2) that of animal bones said to have been cut and worked by the hand of man; and (3) that of flints thought to be artificially fashioned.

On most of these I have already commented elsewhere.[1] Under the first head I may mention the skull discovered by Professor Cocchi at Olmo, near Arezzo, with which, however, distinctly Neolithic implements were associated; the skeletons found at Castelnedolo—of which I need only say that M. Sergi, who described the discovery, regarded them as the remains of a family party who had suffered shipwreck in Pliocene times; and the fossil man of Denise, in the Auvergne, mentioned by Sir Charles Lyell, who may have been buried in more recent times under lava of Pliocene date. On these discoveries no superstructure can be built. The Calaveras skull seems to have better claims to a high antiquity. It is said to have been found at a depth of 153 feet in the auriferous gravels of California, containing remains of mastodon, and covered by five or six beds of lava or volcanic ashes. But here again doubts enter into the case, as well-fashioned mortars, stone hatchets, and even pottery, are said to occur in the same deposits. In the same way the discoveries of M. Ameghino at the mouth of the Plata, in the Argentine Republic, require much further corroboration.

The presumably worked bones which I have placed in the second category, such as those with incisions in them from St. Prest, near Chartres, the cut bones of cetacea in Tuscany, the fractured bones in our own crag-deposits, and numerous other specimens of a similar character, have, by most geologists, been regarded as bearing marks entirely due to natural agencies. It seems more probable that in bones deposited at the bottom of Pliocene seas, cuts and marks should have been produced by the teeth of carnivorous fish, than by men who could only have lived on the shores of the seas, and who have left behind them no instruments by which such cuts as those on the bones could have been produced.

As to the third category, the instruments of flint reported to have been found in Tertiary deposits, those best known are from St. Prest and Thenay, in the North-West of France, and Otta, in Portugal.

These three localities I have visited; and though at the two former the beds in which the flints were said to have been found are certainly Pliocene, there is considerable doubt in some cases whether the flints have been fashioned at all, and in others, where they appear to have been wrought, whether they belong to the beds in which they are reported to have been found, and have not come from the surface of the ground. Even the suggestion that the flints of Thenay were fashioned by the dryopithecus, one of the precursors of man, has now been retracted. At Otta the flakes that have been found present, as a rule, only a single bulb of percussion, and, having been found on the surface, their evidence is of small value. The exact geological age of the beds on which they have occurred is, moreover, somewhat doubtful. On the whole, therefore, it appears to me that the present verdict as to Tertiary man must be in the form of 'Not proven.'

When we consider the vast amount of time comprised in the Tertiary Period, with its three great principal subdivisions of the Eocene, Miocene, and Pliocene, and when we bear in mind that of the vertebrate land animals of the Eocene no one has survived to the present time, while of the Pliocene but one—the hippopotamus—remains unmodified, the chances that man, as at present constituted, should also be a survivor from that period seem remote, and against the species *Homo sapiens* having existed in Miocene times almost incalculable. The *à priori* improbability of finding man unchanged, while all the other vertebrate animals around him have, from natural causes, undergone more or less extensive modification, will induce all careful investigators to look closely at any evidence that would carry him back beyond Quaternary times; and though it would be unsafe to deny the possibility of such an early origin for the human race, it would be unwise to regard it as established except on the clearest evidence.

Another question of more general interest than that of the existence of Tertiary

[1] *Trans. Herts. Nat. Hist. Soc.* vol. i. p. 145; 'Address to the Anthrop. Inst. 1883'; *Anth. Journ.* vol. xii. p. 565.

man is that of the origin and home of the Aryan family. The views upon this subject have undergone important modification during the last twenty years. The opinions based upon comparative philology alone have received a rude shock, and the highlands of Central Asia are no longer accepted without question as the cradle of the Aryan family, but it is suggested that their home is to be sought somewhere in Northern Europe. While the Germans contend that the primitive Aryans were the blue-eyed dolichocephalic race, of which the Scandinavians and North-Germans are typical examples, the French are in favour of the view that the dark-haired brachycephalic race of Gauls, now well represented in the Auvergne, is that of the primitive Aryans. I am not going to enter deeply into this question, on which Canon Isaac Taylor has recently published a comprehensive treatise, and Mr. Frank Jevons a translation of Dr. Schrader's much more extensive work, 'The Prehistoric Antiquities of the Aryan Peoples.' Looking at the changes that all languages undergo, even when they have the advantage of having been reduced into the written form, and bearing in mind the rapidity with which these changes are effected; bearing in mind, also, our extreme ignorance of the actual forms of language in use among prehistoric races unacquainted with the art of writing, I, for one, cannot wonder at something like a revolt having arisen against the dogmatic assertions of those who have, in their efforts to reconstruct early history, confined themselves simply to the comparative study of languages and grammar. But, notwithstanding any feeling of this kind, I think that all must admire the enormous industry and the varied critical faculties of those who have pursued these studies, and must acknowledge that the results to which they have attained cannot lightly be set aside, and that, so far as language alone is concerned, the different families, their provinces, and mutual relations have, in the main, become fairly established. The study of 'linguistic palæontology,' as it has been termed, will help, no doubt, in determining still more accurately the affinities of the different forms of language, and in fixing the dates at which one separated from another, as well as the position that each should occupy on the family-tree—if such a tree exists. But even here there is danger of relying too much on negative evidence; and the absence in the presumed original Aryan language of special words for certain objects in general use ought not to be regarded as affording absolute proof that such objects were unknown at the time when the languages containing such words separated from the parent stock. Not only Professor Huxley, but Broca and others have insisted that language as a test of race is as often as not, or even more often than not, entirely misleading. The manner in which one form of language flourishes at the expense of another; the various ways in which a language spreads, even otherwise than by conquest; the fact that different races, with totally different physical characteristics, are frequently found speaking the same language, or but slightly different dialects of it: all conduce to show how imperfect a guide comparative philology may be so far as anthropological results are concerned. Of late, prehistoric archæology has been invoked to the aid of linguistic researches; but here again there is great danger of those who are most conversant with the one branch of knowledge being but imperfectly acquainted with the other. The different conditions prevailing in different countries, the degrees of intercourse with other more civilised nations, and local circumstances which influence the methods of life, all add difficulties to the laying down of any comprehensive scheme of archæological arrangement which shall embrace the relics, whether sepulchral or domestic, of even so limited an area as that of Europe. We are all naturally inclined to assume that the record of the past is comparatively complete. But in archæology no more than geology does this appear to be the case. The interval between the period of the river-gravels and that of the caves, such as Kent's Cavern, in England, and those of the Reindeer period of the South of France, may have been but small; but our knowledge of the transition is next to none. The gap between the Palæolithic period and the Neolithic has, to my mind, still to be bridged over, and those who regard the occupation of the Belgian caves as continuous from the days of the reindeer down to late Neolithic times seem to me possessed of great powers of faith. Even the relations in time between the kjökkenmöddings of

Denmark and the remains of the Neolithic age of that country are not as yet absolutely clear; and who can fix the exact limits of that age? Nor has the origin and course of extension of the more recent Bronze civilisation been as yet satisfactorily determined; and until more is known, both as to the geographical and chronological development of this stage of culture, we can hardly hope to establish any detailed succession in the history of the Neolithic civilisation that went before it. In the meantime it will be for the benefit of our science that speculations as to the origin and home of the Aryan family should be rife; but it will still more effectually conduce to our eventual knowledge of this most interesting question if it be consistently borne in mind that they are but speculations.

Turning from theoretical to practical subjects, I may call attention to the vastly improved means of comparison and study that the ethnologists of to-day possess as compared with those of twenty years ago. Not only have the books and periodicals that treat of ethnology multiplied in all European languages, but the number of museums that have been formed with the express purpose of illustrating the manners and customs of the lower races of mankind has also largely increased. On the Continent, the museums of Berlin, Paris, Copenhagen, and other capitals have either been founded or greatly improved; while in England our ethnological collections infinitely surpass, both in the number of objects they contain and in the method of their arrangement, what was acccessible in 1870. The Blackmore Museum at Salisbury was at that time already founded, but has since been considerably augmented. In London also the Christy collection was already in existence and calculated to form an admirable nucleus around which other objects and collections might cluster; and, thanks in a great degree to the trustees of the Christy collection, and in a far greater degree to the assiduous attention and unbounded liberality of the keeper of the department, Mr. Franks, the ethnological galleries at the British Museum will bear comparison with any of those in the other European capitals. The collections of prehistoric antiquities, enlarged by the addition of the fine series of urns and other relics from British barrows explored by Canon Greenwell, which he has generously presented to the nation, and by other accessions, especially from the French caverns of the Reindeer period, is now of the highest importance. Moreover, for purposes of comparison the collections of antiquities of the Stone and Bronze periods found in foreign countries is of enormous value. In the Ethnological department the collections have been materially increased by the numerous travellers and missionaries which this country is continually sending forth to assist in the exploration of the habitable world; and the student of the development of human civilisation has now the actual weapons, implements, utensils, dress, and other appliances of most of the known savage peoples ready at hand for examination, and need no longer trust to the often imperfect representations given in books of travel. But besides the collection at Bloomsbury there is another most important museum at Oxford, which that University owes to the liberality of General Pitt-Rivers. It is arranged in a somewhat different manner from that in London, the main purpose being the exhibition of the various modifications which ornaments, weapons, and instruments in common use have undergone during the process of development. The skilful application of the doctrine of evolution to the forms and characters of these products of human art gives to this collection a peculiar charm, and brings out the value of applying scientific methods to the study of all that is connected with human culture, even though at first sight the objects brought under consideration may appear to be of the most trivial character.

So far as the museums more intimately connected with anthropology are concerned, the advance that has been made has been equally well marked. The osteological collections both at the Royal College of Surgeons and at the Natural History Museum have received important accessions, especially in the craniological department; and the notable addition of the Barnard Davis collection to that previously existing in Lincoln's Inn Fields has placed the museum of the college in the foremost rank. The museums at Oxford and Cambridge have also received most important accessions: the one, of the Greenwell collection from British barrows; the other, of the Thurnam collection of skulls.

The value of the small Handbook for Travellers, issued under the title of 'Anthropological Notes and Queries,' has been proved by the necessity for a new edition, towards which the British Association has made a grant. Some delay in the publication of the new issue has taken place, but I hope that the report of the Committee in charge of the work may give assurance of the book being now in a forward state.

The feasibility of assigning trustworthy marks for physical qualifications in candidates for posts either in the military or civil departments of the State has now for some time been attracting more or less of public attention, and the subject has been taken up by the Council of this Association. The result of their communications on this subject with the Government has been made known in their Report, and I need not enter into the history of the correspondence that has passed upon the question. Whatever course may at the present time be adopted, we may, I think, feel confident that eventually due weight will have to be attached to physical capacity in selection for appointments in the military branch of the public service, for which, indeed, at the present time a medical examination has to be passed. Thanks to the ingenuity of Mr. Francis Galton and others, we have now instruments at our command, not only for testing muscular force, breathing capacity, and other bodily characteristics, but also for ascertaining the closeness and rapidity of connection between the organs of seeing and hearing, and the action of the muscles required to be brought into play. In these experiments nervousness no doubt is to some extent a factor, but perhaps the rough and ready test of the South American commander was for ascertaining the presence or absence of nervousness even more effective. When promotion of some officer was about to be made upon the field, the general caused all the possible candidates to be arranged around him, each armed with a flint and steel and a cigarette, and he who first was satisfactorily smoking was promoted then and there.

Connected with the question of general physical capacity is that of the proper appreciation of colours, the absence of which is a fruitful source of danger, both by land and at sea. It is, indeed, impossible to say how often an apparently inexplicable accident may not have arisen from some form of colour-blindness, such as the inability to distinguish red from green, in a person in charge of a ship, a train, or of points on a railway. True, there are some forms of examination to be gone through, both by mariners and railway officials, with the view of testing their powers and correctness of vision; but it is very doubtful whether the tests employed or the manner in which the examinations are conducted can be regarded as in all respects satisfactory. For the purpose of investigating the phenomena, and, if possible, the physical causes of colour-blindness and allied defects of vision, and also with the view of suggesting improvements in the methods of determining the existence of such defects in candidates for maritime or railway employment, the Council of the Royal Society has appointed a Special Committee. Its labours, however, are not yet finished, and no report has hitherto been received from the Committee. I mention the subject as one in which all anthropologists will be interested, and the importance of which must be universally acknowledged. The most singular feature in the case is that the subject, though carefully investigated by several private inquirers, should have waited so long before being submitted to some public or quasi-public body for investigation.

The subjects of an anthropological survey of the tribes and castes in our Indian possessions, and of the continued investigation of the habits, customs, and physical characteristics of the North-Western tribes of the Dominion of Canada, were both recommended for consideration to the Council of this Association by the General Committee at the meeting at Newcastle. We have heard from the report of the Council what has been done in the matter. The rapidity with which the various native tribes in different parts of the world are either modified, or in some cases exterminated, affords a strong argument for their characteristics, both physical and mental, being investigated without delay.

There are, indeed, now but few parts of the world the inhabitants of which have not, through the enterprise of travellers, been brought more or less completely within our knowledge. Even the centre of the dark African continent promises to become as well known as the interior of South America, and to the distinguished traveller who has lately returned among us anthropologists as well as geographers owe their warmest thanks. It is not a little remarkable to find so large a tract of country still inhabited by the same diminutive race of human beings that occupied it at the dawn of European history, and whose existence was dimly recognised by Homer and Herodotus. The story related by the latter about the young men of the Nasamones who made an expedition into the interior of Libya and were there taken captive by a race of dwarfs receives curious corroboration from modern travellers. Herodotus may, indeed, slightly err when he reports that the colour of these pigmies was black, and when he regards the river on which their principal town was situated as the Nile. Stanley, however, who states that there are two varieties of these pigmies, utterly dissimilar in complexion, conformation of the head, and facial characteristics, was not the first to rediscover this ancient race. At the end of the sixteenth century, Andrew Battel, our countryman, who, having been taken captive by the Portuguese, spent many years in the Congo district, gave an account of the Matimbas, a pigmy nation of the height of boys of twelve years old; and in later times Dr. Wolff and others have recorded the existence of the same or similar races in Central Africa. Nor must we forget that for a detailed account of an Acca skeleton we are indebted to the outgoing President of this Association, Professor Flower. It is not, however, my business here to enter into any detailed account of African exploration or anthropology. I have made this incidental mention of these subjects rather from a feeling that in Africa, as well as in Asia and America, native races are in danger of losing their primitive characteristics, if not of partial or total extermination, and that there also the anthropologist and naturalist must take the earliest possible opportunities for their researches. Already the day is past when the similitude drawn by Anaxilas between music and Africa holds good, and even Cornelius Agrippa could no longer maintain that he 'sayeth not amisse: By God, sayeth he, Musicke is even like Affricke; it yearely bringeth foorth some straunge Beaste.'[1]

I have, however, said enough on what I feel are somewhat vague and general topics, and will now ask you to devote your attention to the business of the Section, when, no doubt, many subjects of interest will be more particularly discussed.

The following Papers were read:—

1. *On the Doctrine of Hereditism.* *By* Rev. F. O. Morris.

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2. *Remarks on the Ethnology of British Columbia.* *By* Horatio Hale.

[This Paper forms the introduction to the Report of the North-Western Tribes of Canada Committee. See Reports, p. 553.]

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3. *Notes on the Religion of the Australian Aborigines.* *By* J. W. Fawcett.

The object of this short paper is to dispel an erroneous impression which exists in the minds of many Englishmen and others, that the Australian aborigines have no religion; whereas they do possess one, and that, perhaps, the most simple of all religions.

They believe in a Creator, to whom different tribes give different names; but all such attributes signify Him to be one that is good and great. His teachings are preserved with great care, white persons not being allowed to hear them mentioned. In some tribes women and children are never taught anything concerning this Spirit.

They believe in a future life, and that, as they live on earth, so will they live hereafter, less the terrestrial discomforts; those living wicked lives await a total annihilation.

[1] *Vanitie of Sciences*, cap. 17.

They possess a belief in good and evil spirits, and have a dread of the Wicked One. They have a strict sense of right and wrong, and their laws are very exact, many deeds of guilt being punished by death. They have religious ceremonies, which are always held in secret, in cleared portions of the scrub, called 'boori' grounds, which they hold very sacred, guarding them with great care; and when once the foot of a white person is placed on them they lose all sanctity.

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4. *Notes on the Aborigines of Australia.* *By* J. W. FAWCETT.

This paper traverses some statements made by Mr. Carl Lumholtz, at last year's meeting of the British Association, concerning the Australian aborigines.

'Of a written language there is no trace.' So says Mr. Lumholtz. The Australian aborigines communicate with each other by means of short pieces of wood, on which certain symbols are cut. When these symbols are put together, they form messages, just in the same manner as letters are put together to form words. These pieces of wood are termed 'talking-sticks,' and are not unfrequently sent by the chief of one tribe to the chief of another, many miles distant. The symbols consist chiefly of zigzag lines and long and short incisions. [*Rubbings of two of these 'talking-sticks' were exhibited.*]

Mr. Lumholtz next goes on to state that the aborigines are polygamistic. This is, however, not generally the case: a chief may, and does, but not often, possess more than one wife; but when such is the case, it certainly makes him no richer, as Mr. Lumholtz avers.

'I found no chiefs on the Herbert River,' says Mr. Lumholtz. This is a very erroneous statement, for the tribes on that river, as elsewhere, *do* possess chiefs, and one of them was personally known to the writer.

Mr. Lumholtz next states that 'the Australian black cannot live under civilisation.' He could never have seen them under such conditions, or he would not have so stated. They do live, and are living, under civilisation, and, the more they become civilised, the better they are: some of them are engaged as school-teachers and missionaries in New South Wales, and several of them have their names on the Parliamentary list of voters, thus having the same rights and privileges as white people.

FRIDAY, SEPTEMBER 5.

The following Papers and Report were read :—

1. *On the Yourouks of Asia Minor.* *By* J. THEODORE BENT.

Character of country inhabited by the Yourouks. Cilicia Aspera, formerly inhabited by the Cilician pirates.

Visit to the Corycian caves on the first plateau above the sea. Temple of Corycian Jove. Opinion of the nomads on this cave. The Olbian cave.

Nomad Yourouks employ tombs and ruins of departed Greeks as houses. The hovels which they build, and their idea of the four seasons. Difference in the country since the days of civilisation.

The Yourouks in their tents. Mode of life and occupations. Their wooden implements, musical instruments, beehives, &c. The honesty of the Yourouks. Ideas of treasure-hunting.

The flocks. Description of the sheep. The Toulon camel. Substitutes for coffee and tobacco.

Absence of religion amongst them. Their sacred trees.

Polygamy. Betrothals and marriage festivities. Wife stealing.

Diseases. Their luxuries.

Dealings with the outer world. Contracts with rich Greeks. The tinker, cattle and wool merchants, &c., visit them periodically.

Aniline dyes destroyed their traffic in colours.
Their condition as farmers.

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2. *The Present Aspect of the Jade Question.* *By* F. W. Rudler, *F.G.S.*

It has long been known that implements worked in jade have occasionally been found in ancient graves in France and Western Germany, and in certain Neolithic stations on the Swiss lakes. Some of these implements are wrought in nephrite, or true jade, and others in jadeite. As neither of these minerals had been found *in situ* in Europe, while both were known to occur in Asia, it had been conjectured that the European jade implements must have had an Oriental source, and that either the implements themselves, or the raw materials of which they were made, had been brought to Europe in prehistoric times. But within the last few years Herr Traube, of Breslau, has discovered nephrite in a place near Jordansmühl, and near Reichenstein, in Silesia. Pebbles of nephrite have also been recently recorded, by Dr. Berwerth, from the valleys of the Mur and the Sann, two rivers in Styria. A pebble believed to be of jadeite was found by M. Damour at Ouchy, on the Lake of Geneva, and the same mineral has been recorded from Monte Viso, in Piedmont.

Jade implements are found along the coast of British Columbia and Alaska, and it has been suggested that these, or the raw jade, had been obtained from Siberia, where the occurrence of nephrite is well known. Dr. G. M. Dawson has, however, recorded the discovery of small boulders of jade, partially worked, in the lower part of the Frazer River Valley; and Lieut. Stoney has obtained the mineral *in situ* at the Jade Mountains in Alaska, 150 miles from above the mouth of the River Kowak.

The present aspect of the jade question is, therefore, quite different from that which it presented when the late Professor H. Fischer and others strongly favoured the view that the jade implements of Europe and America had an exotic origin. In both these continents jade has now been found *in situ*, and it seems, therefore, probable that the material of the implements is indigenous, as maintained by Dr. A. B. Meyer for those of the Old World, and by Dr. Dawson, Professor F. W. Clarke, Mr. G. F. Kunz, and others, for those of the New World. If future discoveries should confirm the indigenous view, the famous jade question will be lifted out of the domain of anthropology.

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3. *On the Aryan Cradleland.* *By* J. S. Stuart Glennie.

Introduction.—After sixty years' discussion of exclusively Asian hypotheses, and twenty years' discussion of Asian and European hypotheses, the question now is not so much as to the respective probabilities of an Asian or of a European, as to the respective probabilities of a North German or of a South Russian Cradleland; and the author is disposed, on the whole, to consider the South Russian Cradleland the more probable, and for the following reasons:—

First.—Because of the extraordinary correspondence, as lately pointed out by Dr. Schrader, not only between the flora and fauna indicated by the common words of the Aryan languages, and the flora and fauna of the South Russian Steppes, but also between the mode and conditions of life indicated by the language, and the mode and conditions of life actually now to be seen on the Steppes.

Secondly.—Because in South Russia, between the 45th and 50th (or 55th) parallels of latitude there were the conditions of such a racial intermixture as might naturally have given rise to such a new variety of the white race as the original Aryan clans. For here, from time immemorial, white Alarodians from the south, white Turkomans from the east, and white Finns from the north have met and mingled. And here, also, there may have been great environmental changes caused by the draining-off of the ancient Eurasian Mediterranean.

Thirdly.—Because of such indications of hybridity in primitive Aryan speech, and of connection particularly with the Finnic group of languages, as would correspond with such a racial intermixture as would seem probably to have been effected in this region.

Fourthly.—Because that interlinking of Aryan languages, which is inexplicable on the hypothesis of successive migrations from Asia, may, on the contrary, be at once explained by a common speech in the South Russian area indicated, and by differentiations caused by the reaction of the speech of the Aryanised non-Aryan tribes encountered in the progress of the Aryans eastwards and westwards.

And *Fifthly.*—Because westwards, in the country between the Dnieper and the Carpathians, and eastwards in the country on the upper waters of the Jaxartes and Oxus, there were the conditions of the passage of the Aryans from the pastoral into the agricultural stage; and because, in moving southward from these regions, they would come into contact with, and have their further development fostered by, more highly civilised peoples.

Conclusion.—As will be seen from the last reason assigned in favour of Southern Russia, the question of the Aryan Cradleland connects itself with all these various researches which tend to limit the primitive civilisations to those of Egypt and of Chaldea, and to derive from these civilisations, and particularly from that of Chaldea, all the later civilisations.

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4. '*Is there a Break in Mental Evolution?*'[1] *By* The Hon. Lady Welby.

Religion has been defined as 'consisting wholly and solely in certain acts of deference paid by the living to the ghosts of the dead.' But how does the savage come by the idea of 'ghost'? If evolution consists in a gradually increasing range of adaptation to environment, why should the correspondence between mental evolution and environment become less complete? The introduction of the idea of 'ghost' marks mental degeneration.

If intelligence thus ceased to adjust itself to fact, the law of elimination should assert itself here as in all other cases. The consequences would react on the physical welfare, and the descendants of the superstitious would, on the whole, give way before those of the stronger-minded.

No such aberration of instinct can be traced amongst the animals. We find there no suicidal sacrifice of time, labour, or victims. Why should primitive man be in this so far below their mental level?

It may be urged that the imaginative or figurative power of the savage, like that of the child, lacks a corrective which is subsequently supplied. But why should this corrective have lapsed at all, since we find it throughout organic development in automatic and increasingly complex form?

Where, then, in the developing consciousness does the link with nature fail, and the answer to stimulus go astray?

And even if the majority of primitive men had failed to carry on the organic tradition of adjustment, why was not the tendency preserved amongst a dominant minority? If such a dominant minority is to be found in the early priests and seers, how comes it that they have not left clearer traces of this really valid knowledge? The truest ideas (however simple and even vague) of the elements of experience ought to be the most widely transmitted. Why, then, was the general tendency towards persistent illusion? The growing 'mind' must have lost the primordial ability to penetrate through mask of any kind to reality. But to have thus lost touch with nature ought to lead to the non-survival of the false thinker. Fatal waste of precious opportunity and energy as well as more positive mischief must needs result.

And, further, the tendency to understand and utilise experience must have been universally inherited. Why, then, should it have so generally failed when we come to the imaginative stage?

If the idea of 'spirit' had its origin in primitive man, it would have to undergo

[1] See *Journ. Anthrop. Inst.* 1891.

the most primitive tests, viz., *contact, odour*, and *flavour*. Failure to meet these would mean destruction to the idea, which could not long be supported merely by the evidence of dreams and hallucinations, inevitably conflicting. And yet these ideas, which seem scarcely to be a natural stage in an orderly and continuous development of mental power, *are the concomitants of a brain growth which certainly is both orderly and continuous.*

Reasoning from the analogy of evolution generally, we should surely have expected that the human mind would have been first matter-of-fact and practical, then imaginative, that is, pictorial, image-producing. But the ghost-theory tends to ignore the practical stage, to turn orderly imagination into desultory and riotous fancy—which is at once stereotyped in persistent and often harmful practice—and to restrict the accurate to modern times. But this is at variance with at least some recent discoveries (*e.g.*, the drawings of the Cro-Magnon cave-men).

Finally, *why should the cult of the living, which had been the very condition of all organic advance, give place to such a monstrous paradox as the cult of the dead?*

We are left with two alternatives.

(1) To suppose an absolute break and reversal in the evolution of mind, wherein a permanently distorted picture of the universe is created, and the real and significant suddenly abdicates in favour of the baseless and unmeaning.

(2) To ask whether there is some reality answering to these crude conceptions, which thus form part of a continuous mental development, and may be described as faulty *translation*, rendered inevitable by the scantiness of primitive means of analysis and expression.

To adopt the first alternative is to strike a blow at the doctrine of continuous ascent in evolution. To adopt the second might lead us to conclude that what we want is a greater power of interpreting primitive ideas as expressed in myth and ritual, notably in relation to recent developments and present researches in psychology itself, and the psychological aspects of language.

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5. *On Reversion. By* Miss Nina F. Layard.

In considering the subject of linear evolution the great importance of a clear understanding of the laws of reversion is apparent, for if it can positively be proved that structures common to lower groups occasionally make their appearance in man through this means, a strong point has been gained. It is logically certain that there cannot be a return to a state which has not once existed. But if, on the other hand, such appearances can be traced to an arrest during the process of development, or to sport, the phenomenon shows no connection between higher and lower groups. The opening sentence in Darwin's remarks on reversion in 'The Descent of Man' appears to take all force from the argument which follows. He says :—'Many of the cases here given might have been introduced under the heading "Arrests of Development."'

If we carefully divide positive cases of arrest of development and sports from those which may be, strictly speaking, considered to have the true appearances of reversion, the number diminishes enormously. Microcephalous idiots undoubtedly belong to the former class, likewise the persistence of the divided malar-bone in some adults, and in all probability cases in which the mature uterus is furnished with cornua.

The occasional occurrence of supernumerary mammæ, also of polydactylism, were both practically withdrawn by Darwin from his list of reversions.

Perhaps the most important point to be ascertained is as to the limit of time after which reversion to an earlier type becomes impossible. If there be no limit, then it may be a matter of surprise that reversion is not more constant in man. 'The proportion of blood of any one ancestor,' we are told, 'after twelve generations is only 1 in 2,048,' and yet a tendency to reversion is retained; but if in our veins there is a proportion of early ancestral blood, so considerable as to render the power of reversion possible for unlimited time, we can only wonder that resemblances to early forms do not occur frequently, and not only in rare and doubtful exceptions.

6. *On an Unidentified People occupying parts of Britain in Pre-Roman-British Times. By* Dr. PHENÉ, *LL.D., F.S.A.*

The author of this paper, who has for many years been surveying the ancient roads and routes of traffic in Europe, lately submitted to a learned society at Oxford certain philological evidences, showing particular names and words, which attaching persistently to the Icknield way, and other ancient roads in Britain, led him to examine artificial constructions, roads, and other works in their vicinities. He found that these also were distinctly local to these ways, and connected with them; in this he was supported by a survey lately made for the Devonshire Association.

In the present paper he showed from extensive investigations in France, Italy, &c., that some of the most remarkable of these names continued from Britain to the Mediterranean along ancient routes of traffic mentioned by writers of the highest standing as Cæsar, Cicero, Florus, Strabo, &c.; that these names, as in Britain, were found only on highways of ancient commerce: and from these facts it was inferred that the ancient routes of traffic in Britain were in communication with those on the Continent, and that a great commercial intercourse existed between Britain and the Continent—a view of the case which the summoning by Cæsar of the concourse of merchants in trade communication with Britain supported. Proceeding still further, it was shown from drawings, photographs, &c., made by the author in the various localities, that works and constructions along and in connection with the same routes were so alike as to be identical in design, and therefore, he assumed, in purpose.

These constructors and merchants were not British, and the traffic appears carried back long prior to the time of Cæsar. As the works indicated the direction whence the people came who constructed them, further researches, which he was still prosecuting, might eventually show their nationality.

The same works and names were found existing in Britain at the present time, as well as in the Mediterranean; and the place nomenclature tended to identify them as belonging to the same people.

7. *Report of the Notes and Queries Committee.*
See Reports, p. 547.

MONDAY, SEPTEMBER 8.

The following Papers were read:—

1. *Physical Development. By* Dr. HAMBLETON.

The author brought the results of his investigations on consumption and chest-types before the Association at Birmingham and Manchester. He showed in the former papers that consumption was directly produced by the conditions that tend to reduce the breathing capacity below a certain point in proportion to the remainder of the body, and that it could be both prevented and completely recovered from by the adoption of measures that were based upon that interpretation of its nature. In the latter the author adduced evidence that proved that the size and shape of the chest after birth solely depended upon the conditions to which it was subjected, that there was the same relationship between the size and shape of the other parts of the body and the conditions to which they were subjected, and that this law obtained in the animal and vegetable kingdoms; and he referred to the immense importance of the issues that were raised by those investigations, both from a practical and a scientific point of view.

The author's objects on this occasion were to call attention to the successful practical application of that research, to give instances in which it will be of immense public service, and to urge its general adoption.

Last year, thanks to the courteous and cordial co-operation of Mr. J. E. K. Studd and the Polytechnic authorities, we successfully inaugurated the first society for the protection of its members from the injurious conditions of their surroundings and for securing their development by the application of natural laws. The Polytechnic Physical Development Society consists of about 200 members, and the tables exhibited refer to the measurements of 100 members who have already obtained an increase of the chest girth of one inch and upwards. Their average increase is a little over one inch and three-quarters. It appeared to the author to be both just and expedient to divide the members into three classes, viz., those who had obtained an increase of the chest girth of one to two inches, of two to three inches, and of three inches and upwards, and their corresponding averages are: for the third class over one inch and a quarter, for the second over two inches and one-eighth, and for the first over three inches and three-eighths. A large number have already exceeded, obtained, or nearly obtained, Brent's medium standard. There has also been a considerable increase in the range of movement, and Hutchinson's standard of vital capacity has been greatly exceeded. In the power of inspiration and of expiration the majority of us much exceed Hutchinson's 'remarkable' and 'very extraordinary' classes. That increase has taken place in small as well as in large chests, whether the men were tall or short, under or over 21 years of age, and with or without gymnastic training. Our members are engaged in over fifty different trades and occupations, amongst them being clerks, compositors, printers, watchmakers, carpenters, engineers, drapers, warehousemen, &c., and they are engaged in those occupations from eight to twelve hours daily. Neither less instructive nor less significant are the variations in the chest girth that have taken place during the year. Some of our members are prominent members of the gymnasium, and as such have energetically prepared for the various events that were taking place in connection therewith. The author has frequently noted a large decrease of the chest girth on such occasions. The girth has also decreased when the men were much engaged in extra work, stocktaking, cycling, &c., or when they neglected to follow the directions given them. In fact, the increase or decrease observed has been in direct relationship with a corresponding change in the conditions of their surroundings. But it is not only in the ordinary routine of daily life that this relationship between the chest girth and the conditions to which it is subjected is manifested. In the treatment of consumption the author has obtained increases of from two to three inches and upwards. This increase of the chest girth is accompanied by a corresponding increase of the range of movement and of the vital capacity, and by a change in the type of chest from that of disease to that of health, for the author is happy to be able to state that that treatment of the disease has been completely and invariably successful. In the presence of evidence of this nature, he would offer but a word of comment. What has been experimentally obtained has been also equally well obtained in the practical application of that research. One part of the investigations confirms the other, and the case as a whole is complete and practicable. The conditions by which these results were obtained were then referred to.

The author briefly referred to three cases in which the introduction of physical development would render an immense public service, viz., the army, life assurance and sick benefit societies, and the education of children.

The cases above noted urgently require the introduction of physical development, but where shall we find in civilised countries men upon whom its adoption would not confer a great benefit? Some time ago Sir Andrew Clark directed public attention to the increasingly injurious effects of progressing civilisation, and to the inability of hygiene and sanitation to counteract them. That is true, but here we have a new and most effective means of dealing with them, for by it we can turn these very forces themselves to our own protection and advantage. We have the knowledge and the power to stamp out consumption, the great curse of civilisation. Shall we not complete the investigation for the remainder of the body, and so obtain and maintain, in the presence of further advances of civilisation, the highest physical development of man?

The Polytechnic Physical Development Society.

(Average increase of 100 Members $1\frac{3}{4}+\frac{47}{400}$ inches.)

CLASS I.—*Average increase* $3\frac{3}{8}+\frac{5}{56}$ *inches.*

Initial.	Occupation.	Hours.	Age.	Height.	Chest.		Girth.		Increase.
					Insp.	Exp.	Insp.	Exp.	
B. F.	Packer	9	20	5 ft. 8½ in.	35	32	38	32	3
B. A.	Tailor	10	17	5 6½	34¾	32	38	32	3¼
B. W. H.	Tailor	10½	22	5 7¼	36½	32½	40¼	33	3¾
B. J. A.	Clerk	10	27	6 1	36¼	33⅛	39¼	34¼	3
C. J. H.	Painter	9½	18	5 8¾	35	31	38	32	3
J. W. G.	Umbrella Maker	11	27	5 7¾	32½	30½	35¾	30½	3¼
J. T. C.	Wharfinger	11	22	5 10⅜	36¾	35½	39⅞	34¼	3⅛
M. J. H.	Clerk	8	16	5 5⅛	32½	30	35½	31½	3
M. J.	Tailor	9	18	5 7½	34½	32	41	35	6½
R. W. R.	Compositor	9½	18	5 7⅜	34¼	32½	37½	32½	3¼
S. A. H.	Iron Salesman	8	24	5 8	36	34	39	33	3
S. H. G.	Dentist	8?	19	4 11	30¾	29	34¾	33½	4
S. J.	Contractor	10?	—	5 1⅜	34⅛	32¼	37½	32½	3⅜
W. L.	Salesman	12	17	5 10	34½	32	37½	33½	3

2. *On some Archæological Remains bearing on the question of the Origin of the Anglo-Saxons in England.* *By* ROBERT MUNRO, *M.A., M.D.*

The author of the 'Viking Age' maintains that the so-called Anglo-Saxons in England are of Scandinavian origin, and this theory he attempts to substantiate by two main lines of argument—viz. (1) by an analysis of the Sagas and other historical documents of Western Europe; and (2) by a comparison of the antiquities found in England and in Scandinavia.

In a subsequent correspondence which appeared in the 'Times,' M. Du Chaillu challenged archæologists to point out any remains in any other part of Europe so like those of the early Anglo-Saxons in England as the relics he figures from Scandinavia. In the regions at the mouth of the Elbe and the Western Coasts of Germany and Holland, from which, according to the generally accepted opinion, the earlier Anglo-Saxon immigrants hailed, there do not exist, according to him, any analogous remains at all. More recently, in a lecture delivered in Edinburgh under the auspices of the Geographical Society of Scotland, M. Du Chaillu stated that he gave up the historical part of his argument and now relied chiefly on the archæological data. At the meeting of the Association last year his theory was under discussion, and in these circumstances it may be of interest to lay before the present meeting a short account of some remarkable remains recently brought to light on the coasts of Holland and North Germany, more especially in Friesland and the low-lying district northwards as far as the River Elbe, a geographical area which strikingly coincides with the traditionary cradle of our Anglo-Saxon forefathers.

The antiquities in question are found in flattish mounds of varied extent, sometimes covering many acres, which go under the name of *Terpen* in Friesland, *Warfen* in the district around Emden, and *Wurthen* in the Dithmarschen bordering on the Elbe.

Dr. Munro then gave a short description of the structure and contents of these mounds, and argued that the relics showed a remarkable similarity to Anglo-Saxon antiquities found in England. It is unnecessary to give an abstract of this communication, as ample details of these discoveries are published in the author's work, 'The Lake-Dwellings of Europe,' in which the subject is discussed under the title of 'Ancient Marine Dwellings.'

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3. *Some Neolithic Details.* *By* H. Colley March, *M.D.*

Ten years ago, while a scrutiny was being made of a number of tiny flakes that had been picked up with the only thought that they proved the existence of a veritable Neolithic floor, it was perceived that some of the fragments were, in truth, beautifully wrought after a fixed type or pattern.

At that time these minute stone implements, from the hills about Rochdale, were the smallest that had been found in any part of the world. Since then precisely similar tools have been met with in India, and last summer the author discovered some in the Isle of Man.

They are of three principal types: (1) those that taper to a point; (2) those that are semilunar; and (3) those that are shouldered like a penknife. Some of them do not measure more than $\frac{1}{4}$ inch in length.

The pointed ones are unmistakably awls, and would serve to drill eyes in bone needles, and to puncture holes in the hide through which the needle might pass. The semilunar implement can hardly be anything else than a fine saw; it is rather rare, and it sometimes shades off into the shouldered form. Those that are shouldered like a penknife are very numerous, and have this peculiarity, that when they are placed with their flat surface downwards the hump or angle is on the left-hand side. It has been suggested that these implements were used to constitute the teeth of a harpoon. But it seems unlikely that any dwellers on the flanks of the Pennine chain or in the caves of the Vindhya Hills of India could have had much opportunity of using a harpoon; whilst the extraordinary delicacy of workmanship which these tools display, their remarkable uniformity of style, and the careful serration of their straight edge strongly suggest that they were mounted on handles for cutting and engraving in the manufacture of implements of bone, horn, and wood, such as needles, arrow-shafts, and possibly combs. These minute stone tools have been made of flint, of chert, of agate, and of quartz.

It has been said that the bulb of percussion cannot be produced on quartz. The author showed flakes of quartz, quartzite, greenstone, chert, hæmatite, and even of chalk, all of which presented a well-marked bulb of percussion. They were found on the Neolithic floor.

Pieces of chalk are often found in tumuli of the Stone Age. Some of these, as well as fragments of graphite and of hæmatite that have striations on two sides, such as would be caused by rubbing them on a slab of sandstone, were exhibited. The substances were used as pigments.

Discarding the negative colours, black and white, and assuming it to be the fact, as generally stated, that of the positive colours, the first used was red, the second yellow, and the third blue, the question arises, Can any reason be assigned for this order of choice in early decoration? The modern artist's quarrel with Nature is a double one. He says that she is badly lighted, and that she is *too green.* Now, it is certain that if we look intently at a green figure, and then cast the eyes on a neutral surface, we see the same figure *in red.* To those who behold only the green of Nature a red spectrum is always potentially present. Their retina needs this complementary colour as a refreshment, and the primitive artist employs it in unconscious obedience to a physiological law. Yellow would come next, as the most restorative colour, and blue last.

On certain Neolithic materials shiny lines and streaks may be seen. Some persons think them due to blown sand, or to the friction of siliceous grasses. Dr. Blackmore, of Salisbury, thinks they are caused by worms—that the stone happened to lie in a worm-track, and that the worm, by perpetually passing and repassing, polished it. A microscopic examination shows that in some cases the glazed mark is produced, not by friction, but by a deposit of silica, and it is often more apparent in the depressions of an irregular surface than on its elevations. Examples of it on flint, chert, quartzite, and hæmatite were exhibited.

4. *On Prehistoric Otter and Beaver Traps.* By ROBERT MUNRO, *M.A., M.D.*

In this communication the author describes some curious wooden machines which have been discovered in various peat bogs in different parts of Europe, and of which hitherto no satisfactory explanation has been offered. His attention was first directed to the subject by the late Dr. Deschmann, curator of the Landesmuseum at Laibach, who had in his custody two of these objects, one being in an excellent state of preservation. They were both found in the great Laibach moor, in the vicinity of the famous group of lake-dwellings then being investigated in that locality. The most perfect of the two was made of a solid piece of oak, measuring 32 inches long, 12 broad, and 4 deep. It tapered a little at both extremities, and contained a rectangular aperture in the middle, measuring 9 inches long by 5 broad, which was closed by two movable valves worked by pivots projecting into corresponding holes in the framework. These valves were freely movable when pushed upwards, but this motion was arrested just a little short of the perpendicular by the slanting shape of their posterior edges, so that when left to themselves they always fell down, and so closed the aperture.

These machines, not being actually found on the site of the lake-dwellings, though at the same depth in the peat, were not at first included among the relics from these habitations, and so they lay in the museum for several years as objects of a *sui generis* character, until some German anthropologists visited the locality and pointed out their similarity to a series of wooden objects that had been found in North Germany. One of the objects thus referred to, and the first discovered, is figured and described by Dr. Hildebrandt, of Tribsees, in the 'Zeitschrift für Ethnologie' ('Verhand.' for 1873), vol. v. p. 119, who conjectures that it had been used attached to a net for catching fish.

In the following year, Professor F. Merkel, of Rostock, in reply to Dr. Hildebrandt's communication (*ibid.* vol. vi. p. 180), figures and describes a similar object found in the moor of Samow, and then preserved in the museum of Rostock, which was considered by sportsmen to have been a trap for catching otters. A few years later (1877), Dr. Friedel announced the discovery of a third example, which had been found in a moor at Friedrichsbruch, near Flatow, in the province of West Prussia (*ibid.* vol. ix. p. 162). All these objects were buried in the peat to a depth of 6 or 7 feet.

Profiting by the suggestions thus received, and considering the character of the fauna of the lake-dwellings at Laibach, which yielded an enormous number of the bones of the beaver (representing at least 140 individuals) but none of the otter, Dr. Deschmann and his assistant came to the conclusion that the Laibach machines were beaver-traps.

Quite recently, Dr. Meschinelli, of the Geological Museum of the R. University of Naples, published a memoir on some prehistoric remains discovered at Fontega, a small valley which opens into Lake Fimon, near Vicenza, in North Italy ('Atti della Soc. Veneto-Trent. di Sc. Nat.' vol. xi.). Among the objects figured in this memoir is a wooden boat-shaped object, 28 inches in length, containing two central valves, which Dr. Munro at once recognised as analogous to the objects found at Laibach and in North Germany. Dr. Meschinelli states that two more were discovered in the course of his investigations, which, though less perfectly preserved, were, so far as he could judge, precisely similar to the one figured in his memoir. When Dr. Meschinelli wrote his memoir he was unaware of the discovery of similar objects elsewhere in Europe, and he was much puzzled to account for their use, conjecturing that they might have been models of boats. After the principal facts in regard to the previous discoveries were laid before him, he has published a second memoir ('Rend. della R. Accad. delle Sc. Fis. e Matemat. di Napoli,' 1890), in which he criticises and rejects all the previous explanations, so far as applicable to the Fontega machines, but comes to the conclusion that they were used as traps for catching wild birds, such as water-fowl.

What still further enhances the interest in this subject is the fact that, as early as 1859, a wooden implement which evidently comes under the same category was found in a bog in the townland of Coolnaman, County Derry, Ireland.

Fortunately this machine was figured and described in the 'Ulster Journal of Archæology' (vol. vii. p. 165) as an 'antique wooden implement,' but as to its use no rational explanation has ever since been given. One thought it was a fish-trap intended to be placed in a river; another, that it was a kind of pump; a third, that it was a machine for making peats; and a fourth, that it was a cheese-press. The only noteworthy difference between the Irish machine and its analogues on the Continent is that the former has its central aperture closed by one valve instead of two.

To find so many of these machines, of unknown use and so remarkably similar in structure, in such widely separate districts as Ireland, North Germany, Styria, and Italy, must be a matter of interest to archæologists, and no one can say that the correct explanation of their use is to be found in any of the suggestions hitherto offered on this point. In helping to solve this problem, Dr. Munro, in conclusion, directed attention to an important factor—viz. that all the examples from Italy, Laibach, and Ireland were found in bogs which in earlier times had been lakes. This may be also true as regards those from North Germany; but the point is not referred to in the short notices that have appeared of them. If these machines are really traps, they could be used only in water, where the animal could insert its head from below; and, among amphibious animals, the otter and beaver are the only ones to which all the conditions involved in a trap theory would apply.[1]

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5. *Indications of Retrogression in Prehistoric Civilisation in the Thames Valley.*[2] *By* H. STOPES, *F.G.S.*

The author exhibited seventy-four flints, consisting of forty-five celts, &c., of a rough and rude type, that have been fashioned from polished Neolithic celts and tools, twelve scrapers, and seventeen polishers from the same source.

Of these a few are possibly doubtful, as they are fragments, and the polished surface existing upon them is small. Of over sixty specimens, however, there cannot be a reasonable doubt but that they have been intentionally and deliberately chipped to their present form. It is evident that they are not the result of accident or of normal wear and use.

They all come from the Upper Thames Valley, between Oxford and Reading. With one exception they are flint. None of them show signs of recent fracture, and all have the peculiar white or brown surface acquired by flint under lengthened exposure. The author has a large collection of worked flints from the Thames, from which (and helped by Mr. W. R. Davies, M.N.S., Wallingford) the specimens were selected.

The author suggests that the flints show that a tribe up the Thames had attained the comparatively high degree of civilisation indicated by perfectly made and polished tools, of which so many still exist. For some reason this more cultured race or tribe was vanquished by a more barbarous nation from the North or West. These ruder people could not, or would not, use the more perfect tools of the conquered race, as they needed more skill to make, and greater intelligence to handle, to keep in order, and to mount. These ruder men had not the necessary intelligence; hence they took the tools and worked them back to a form they understood, and by so doing furnished the evidence of retrogression in prehistoric civilisation.

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6. *On the Duggleby 'Howe.'*[3] *By the* REV. E. MAULE COLE, *M.A., F.G.S.*

In July last Sir Tatton Sykes, Bart., commenced the opening of the great mound at Duggleby, on the Yorkshire Wolds. The work was entrusted to the care of Mr. T. R. Mortimer, the well-known antiquarian, and occupied six weeks.

[1] For further details see *Lake-dwellings of Europe* and *Proc. of S. A. Scot.* January 12, 1891.

[2] Published *in extenso* by the author with same title, pp. iv, 16, quarto. (Leeds: Goodall & Suddick.) 1890.

[3] *Proceedings of Yorks. Geol. Soc.* vol. xi. part iii.

The diameter of the mound was found to be over 120 feet; originally the height was about 30 feet, but the summit had been more or less flattened. In the process of excavation it turned out there was an outer mound of rough chalk, of some 15 feet or more in thickness, surrounding an inner mound, and that the centre of the two did not exactly correspond.

The inner mound showed an unbroken covering a foot thick, of Kimeridge clay, underneath which was a concentric layer, $4\frac{1}{2}$ feet thick, of fine chalk grit, resting on a bed of clay $5\frac{1}{2}$ feet thick.

In the grit and lower clay were found fifty-three deposits of burnt human bones, but without any urns. There were two graves cut out of the solid rock: one in the centre, 9 feet deep, containing three bodies; and a shallow one close by, containing one body, accompanied by many flint flakes and tusks of the wild boar. Some beautiful flint weapons, with a fine polished flint axe, were found with the upper body in the central grave. Altogether eleven interments, doubled up in the usual way, were met with, all below the clay mantle of the inner mound. No pottery occurred, with the exception of a food vase at the bottom of the central grave. No trace of bronze was seen. Fragments of broken human bones, and especially of skulls of infants, were found scattered about in the clay and grit.

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7. *A probable Site of Delgovitia.* *By* T. R. Mortimer.

At a point in the parish of Wetwang-with-Fimber, on the Yorkshire Wolds, where the Roman road from York to the coast crosses the Roman road from Malton to Beverley, the writer has discovered a Romano-British graveyard: the bodies, fourteen in number so far, orientated, with no pottery. Close by a number of peculiar trenches were found, in form like a gridiron, in which were numerous animal bones and fragments of Roman pottery.

The writer thinks that the trenches might have been constructed to convey water, which would otherwise sink in the valley gravel, to a small Roman station. The probability of this situation for the long-lost Delgovitia has already been stated by Phillips and Akerman, the distance agreeing exactly with the itinerary, supposing Stamford Bridge to be Derventio, and Flamborough Head, Prætorium.

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8. *A supposed Roman Camp at Octon.* *By* T. R. Mortimer.

At Octon, close to a Roman road running from York to the coast, is a well-preserved camp, divided into two portions by a ditch and mounds. The eastern portion measures 80 yards by 68 yards. The western is slightly larger, but less perfect. The entrance was in the centre by the above-named subway, and the defensive position was exceptionally strong. The rectangular corners of the camp and the width of the ditches ($7\frac{1}{2}$ feet) at the bottom, in addition to its position, encourage the writer in believing that this is not a British work, but Roman.

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9. *A Suggestion as to the Boring of Stone Hammers.* *By* W. Horne.

TUESDAY, SEPTEMBER 9.

The following Papers and Reports were read:—

1. *Old and Modern Phrenology.* *By* Bernard Hollander.

It is now almost a century since Francis Joseph Gall, strongly impressed by the fact that certain formations of the head correspond to definite peculiarities of character, began to reduce his conclusions to the system now known as Phrenology.

From the very outset it was opposed chiefly because the phrenological localisations appeared to be incapable of physiological demonstration, but also, no doubt, from a spirit of opposition to the extravagant claims of some of Gall's successors. And it is partly due to the irresponsible enthusiasm of some of these that phrenology has fallen into low estimation.

The work of leading physiologists of the present day has brought facts to the fore, proving, if not absolutely, at any rate in a circumstantial manner, not only the truth of the theory of localisation, but in many cases the actual correctness of Gall's empirical observations.

It is now finally granted that all mind manifestations *are* dependent on brain-matter; that the various elements of the mind *have* distinct seats in the brain, a few of which have been actually determined, and that recent researches in physiology and pathology have, in many cases, established the physiological correlative of psychological actions. Thus the most intense centre for movements of the facial muscles have been proved to be the brain-area, in which Gall located his organ of mimicry or imitation; the gustatory centre in the same region is the so-called gustativeness of the phrenologists. The motor area for the concentration of attention, as assumed by some physiologists, is found to correspond with the localisation of concentrativeness; and Dr. Voisin's theory on the centre of exaltation is in harmony with George Combe's speculations. Mr. Herbert Spencer made an apparently successful localisation of a supposed faculty of reviviscence, for which there is much pathological evidence; and the so-called centre for psychical blindness, as localised by Munk, corresponds with Gall's observations.

These are, of course, not all the facts which can be brought forward in support of the broad principles of phrenology. More can be gathered in the works of men like Broca, Hitzig, Fritsch, Ferrier, Horsley, Schäfer, Wundt, Munk, Goltz, Nothnagel, Exner, Brown-Sequard, and very many others, who occupied themselves with the localisation of the functions of the brain, and who have created a new system curiously similar to the old one. Brain physiology is still an obscure subject; and the coincidence in the results of modern investigations with the old empirical observations augurs well for the establishment of Gall's theories on a sound scientific basis.

All that phrenology asserts is that, with the assistance of certain known elements—such as physical temperament, education, and surroundings—positive conclusions as to psychical character can be drawn from the configuration of the skull; and, in the light of the present condition of physiological science, this claim can surely be considered neither illogical nor extravagant. The theory itself presents such varied interest, and promises, if properly utilised, to be of such immense value to education, that it must be admitted that it is at least well worth the effort of serious investigation.

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2. *Stethographic Tracings of Male and Female Respiratory Movements.* *By* Dr. Wilberforce Smith.

A fresh investigation of the commonly received theory that men and women essentially differ as to their respiratory movements has at its present stage elicited the tracings now exhibited. They have been taken from about fifty persons by means of Burdon Sanderson's stethograph, and more recently by a modification of that instrument which the author has employed for greater convenience, accuracy, and rapidity of application. Tracings have been taken from four, and in many cases from five, different points in the mesial line of the thorax and abdomen anteriorly. Certain general results belonging to nearly all the cases, whether of men or women, are seen to be as follows:—*Over the sternum,* at the level of the second rib, there is ample movement, which, taken with the dress completely loosened, is about equally free in the two sexes. *Over the liver,* in the mesial line below the ensiform cartilage, there is constantly free and very regular movement in both sexes. *Just above the umbilicus* the results are variable, and appear to depend largely on the size of the liver and the degree of abdominal plethora or slightness, a firmer condition of the abdominal contents serving more readily to convey the diaphragmatic movements. Midway *between the umbilicus and the pubes* very variable results appear, a large proportion of cases, whether male or female, showing that respiratory movements at this lower level are no longer conveyed distinctly to the surface except when the abdomen is particularly firm.

Just below the umbilicus the most characteristic results are to be noticed, according to which the tracings have been divided into the following groups:—

1. From male cases, a group showing free movement below the umbilicus—to this group most of the men belong. A smaller group of males, mostly with soft abdominal walls or contents, exhibits only slight movement.

2. Of women attired and corseted in the ordinary manner, but having the dress completely loosened during the application of the stethograph, there is a large group which shows greatly diminished movement below the umbilicus. On the other hand, a very small group of young women (corset-wearers) shows free movement below the umbilicus.

3. Of women who habitually wear no corset, and who are of all ages, there is a large group showing free movement below the umbilicus in no way less marked than in male cases. On the other hand, a small group (two cases) with slight soft abdominal walls and contents, but habitually wearing no corset, shows only a trifling degree of movement just below the umbilicus.

Thus, so far as the present investigation has yet proceeded, it wholly fails to confirm the view commonly put forth in physiological text-books, that there is a natural difference between the sexes in regard to respiratory movements.

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3. *A new Spirometer.* *By.* W. F. STANLEY, *F.G.S.*

This instrument is constructed upon the principle of the class of gas meters used for testing, but as the quantity of air to be measured is very small, or about 200 cubic inches only, the construction of the instrument is made very light and delicate, so that a pressure equal to ·2 inch of water is sufficient to overcome the inertia of the mechanical parts of the instrument, which consist of a balanced hand and a short train of watch wheels. The air acts upon a set of light cellular fans, which are placed round an axis partly placed in water. The expiration is conducted by the mouthpipe to near the axis of the fans, and passes beneath the fans on one side of the axis only. By this means the fans are consecutively floated up by the pressure of the water on the air. The action is constant, so that resistance to the intrusion of the breath is not greater at one time than another, as it is with the pneumatic spirometer, and it is impossible for any air to escape until measured. The index hand becomes fixed when the muscular power of the lungs ceases to expire air at a pressure of ·2 water inch. The apparatus registers about 10 per cent. more air expired than the best-made Hutchinson apparatus made upon the pneumatic principle. The hand is brought back to zero by pressing a button connected with a pressure spring on the front of the instrument.

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4. *Report of the Anthropometric Laboratory Committee.*
See Reports, p. 549.

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5. *Diagrams for Reading-off Indices.* *By* Dr. WILBERFORCE SMITH.

To ascertain easily and quickly the percentage relation between two numbers is the aim of the diagrammatic method described in this communication. The method is not less applicable to other numerical records than to those of anthropometry, but it is in regard to the latter that the author has felt and sought to supply a need. It occurs to the subject himself of nearly every anthropometric investigation, to inquire how his weight, breathing capacity, &c., compare with an average or mean standard; and when the investigator seeks to make the best use of large numbers of records, the labour and time involved in working out percentage calculations become very considerable. It is true he may be aided by certain existing tables for ready-reckoning, but these apply to only a limited number of the possible combinations of figures which he has to deal with. Indeed, if records are made in numbers of only three figures, it will readily be perceived that the possible combinations of actual and average numbers amount to hundreds of thousands.

The diagrammatic method which the author's own wants have led him to attempt, may be briefly explained by the following directions for constructing a diagram. Take a sheet of 'quad'-ruled paper—that is, of paper evenly divided into minute squares. Then on its horizontal lines mark off a scale of numbers having any convenient range, say from 150 below to 300 above. Call this the 'horizontal scale.' Next traverse this scale by an oblique 'percentage scale,' whose lines may conveniently be of a different appearance—for instance, of a red colour. To construct this percentage scale, first rule a 100 per cent., or 'par' line, beginning from 150 on the left of the horizontal scale and sloping up to 300 on its right. Number it as 100 at both ends, say, in red figures. Then fill in other oblique red lines to form the percentage scale. Construct, for instance, a + 10 per-cent. oblique line, beginning on the left of the horizontal scale at 150 + 10 per cent. (= 165), and reaching on its right to 300 + 10 per cent. (= 330). Then, if the ruling have been accurately done, it will appear that at every intermediate point, this + 10 per cent. (red) line has its course 10 per cent. higher than any number on the 100 per-cent. line—that is, 10 per cent. above any number between 150 and 300. Similarly construct oblique lines for all convenient percentages above or below the 100 per-cent. line, and so complete the percentage scale.

The range of 150 to 300 as a 100 per-cent. line has been taken as an instance, but the method may, by the use of several diagram sheets, be readily applied to all numbers up to, say, 1,000 and its percentages. A leading method of employing such diagrams is (*a*) to find on the 100 per-cent line the position of any average number required; (*b*) to keep by means of a 'set-square' the vertical line of that number; (*c*) to find on the horizontal scale the actual number to be compared; (*d*) to keep the horizontal line of that number; (*e*) to note the intersecting point of such vertical and horizontal lines, and at that point to read off on the percentage (red) scale the percentage relation of the two numbers. Amongst other uses may be obviously that of ascertaining the percentage relation or 'index' of two diameters, for instance, of different parts of the human head, trunk, or limbs, but particularly any diameters which do not fall within existing published tables.

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6 *Excavation of the Wandsdyke at Woodyates.* *By* General Pitt-Rivers, *F.R.S.*

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7. *Notes on Human Remains discovered by General Pitt-Rivers at Woodyates, Wiltshire.* *By* J. G. Garson, *M.D., V.P. Anthrop. Inst.*

The author described a series of human osteological remains discovered by General Pitt-Rivers near Woodyates during the last two years, which, through the kindness of General Pitt-Rivers, he had an opportunity of examining. The data for the communication were drawn from his own observations and from the measurements of the skulls and other bones of the skeleton, made by General Pitt-Rivers and placed at his disposal for the purpose.

General Pitt-Rivers's measurements of the limb bones showed the stature of the individuals to have been greater than that of the persons who were interred in Woodcuts and Rotherley, Romano-British villages, described by General Pitt-Rivers in his works on these settlements.

The characters of the skulls showed a considerable range of variation in size and proportion, indicating that they did not belong to a homogeneous race, but to individuals of mixed race. Variation was found, not only in the facial portion, but also in the form of the brain case or calvaria. The outline of the latter ranges from a long and narrow to a moderately broad oval. The parietal bosses are, as a rule, not pronounced. The sutures tend to show extreme conditions, either being very open or nearly obliterated, although the skulls are chiefly those of adults not apparently far advanced in life. Four instances of metopism, or persistence of the median frontal suture, occur in the seventeen skulls examined, which is a higher percentage than usual among modern skulls. In these metopic skulls the forehead is broad and the frontal bones well marked. In the other specimens the forehead is receding to a greater or less extent. The muscular ridges above the eyes and at other parts of the skull and the glabella are, as a rule, moderately developed. When viewed from the front it is seen that the arch of the vault of the cranium is moderately high and follows a well-proportioned curve in about one-third of the specimens, in about a third of them it is very acute or pointed at the apex, while in the remainder it is very flat. The cephalic index varies from 69·2 to 82·6. Two of the crania are brachycephalic, nine are mesaticephalic, five are dolichocephalic, and one is hyper-dolichocephalic. The breadth of the calvaria exceeds the height in all the specimens, except one in which the height is greater than the breadth by 1 mm. The form of the face is long and narrow in some cases, while it is short and proportionately broad in others. The nasal index shows great diversity in the form of this part of the face, varying from 33 to 58. Six of the specimens are leptorhine, four mesorhine, and two are platyrhine. The shape of the orbits is very diverse, as well as the angle at which they are set. A maxillary notch is present in some cases and not in others. The face is straight, no particular prominence of the alveolar part of the maxillæ being observable. The chin is long and pointed in some cases, short and square-like in others.

These human remains from Woodyates present much more mixed characters than either the Woodcuts or Rotherley series, the latter being the most homogeneous of the three sets. As far as the author is able to judge, the mixture is due to crossing between the Romans and the early dolichocephalic British race. There is no evidence of mixture arising from crossing occurring between either of these races and the Celtic population.

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8. *Report of Prehistoric Inhabitants Committee.*—See Reports, p. 548.

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9. *Report of the Nomad Tribes of Asia Minor Committee.*
See Reports, p. 535.

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10. *Report of the North-Western Tribes of Canada Committee.*
See Reports, p. 553.

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11. *Report of the Indian Committee.*—See Reports, p. 547.

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[*An asterisk (*) signifies that no abstract of the communication is given.*]

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1871. *Ainsworth, John Stirling. Harecroft, Cumberland.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.
AIRY, Sir GEORGE BIDDELL, K.C.B., M.A., LL.D., D.C.L., F.R.S., F.R.A.S. The White House, Croom's Hill, Greenwich, S.E.
1871. §Aitken, John, F.R.S., F.R.S.E. Darroch, Falkirk, N.B.
Akroyd, Edward. Bankfield, Halifax.
1884. *Alabaster, H. 22 Paternoster-row, London, E.C.
1886. *Albright, G. S. The Elms, Edgbaston, Birmingham.
1862. ‡ALCOCK, Sir RUTHERFORD, K.C.B., D.C.L., F.R.G.S. The Athenæum Club, Pall Mall, London, S.W.
1861. *Alcock, Thomas, M.D. Oakfield, Sale, Manchester.
*Aldam, William. Frickley Hall, near Doncaster.
1887. ‡*Alexander, B. Fernlea, Fallowfield, Manchester.*

Year of
Election.

1883. ‡Alexander, George. Kildare-street Club, Dublin.
1888. *Alexander, Patrick Y. 8 Portland-place, Bath.
1873. ‡Alexander, Reginald, M.D. 13 Hallfield-road, Bradford, Yorkshire.
1858. ‡ALEXANDER, WILLIAM, M.D. Halifax.
1883. ‡Alger, Miss Ethel. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
1867. ‡Alison, George L. C. Dundee.
1859. ‡Allan, Alexander. Scottish Central Railway, Perth.
1885. ‡Allan, David. West Cults, near Aberdeen.
1871. ‡Allan, G., M.Inst.C.E. 10 Austin Friars, London, E.C.
1871. ‡ALLEN, ALFRED H., F.C.S. 67 Surrey-street, Sheffield.
1887. *Allen, Arthur Ackland. Overbrook, Kersal, Manchester.
1879. *Allen, Rev. A. J. C. Cava House, Barton-road, Cambridge.
1887. *Allen, Charles Peter. Overbrook, Kersal, Manchester.
1888. ‡Allen, F. J. Mason College, Birmingham.
1884. ‡Allen, Rev. George. Shaw Vicarage, Oldham.
1887. §Allen, John. Kilgrimol School, St. Anne's-on-the-Sea, viâ Preston.
1878. ‡Allen, John Romilly. 5 Albert-terrace, Regent's Park, London, N.W.
1861. ‡Allen, Richard. Didsbury, near Manchester.
1887. *Allen, Russell. 2 Parkwood, Victoria Park, Manchester.
1889. ‡Allhusen, Alfred. Low Fell, Gateshead.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
1889. §Allhusen, Frank. Low Fell, Gateshead.
*ALLMAN, GEORGE J., M.D., LL.D., F.R.S. L. & E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. Ardmore, Parkstone, Dorset.
1887. *Allnutt, J. W. F., M.A. 12 Chapel-row, Portsea, Hants.
1886. ‡Allport, Samuel. 50 Whitall-street, Birmingham.
1887. ‡Alward, G. L. 11 Hamilton-street, Grimsby, Yorkshire.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1883. §Amery, John Sparke. Druid House, Ashburton, Devon.
1883. §Amery, Peter Fabyan Sparke. Druid House, Ashburton, Devon.
1884. ‡Ami, Henry. Geological Survey, Ottawa, Canada.
1876. ‡*Anderson, Alexander. 1 St. James's-place, Hillhead, Glasgow.*
1878. ‡*Anderson, Beresford. Saint Ville, Killiney.*
1885. ‡Anderson, Charles Clinton. 4 Knaresborough-place, Cromwell-road, London, S.W.
1850. ‡Anderson, Charles William. Belvedere, Harrogate.
1883. ‡Anderson, Miss Constance. 17 Stonegate, York.
1885. *Anderson, Hugh Kerr. Frognal Park, Hampstead, London, N.W.
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1888. *Anderson, R. Bruce. 35A Great George-street, London, S.W.
1889. ‡Anderson, Robert Simpson. Elswick Collieries, Newcastle-upon-Tyne.
1887. ‡Anderson, Professor R. J., M.D. Queen's College. Galway.
1880. *ANDERSON, TEMPEST, M.D., B.Sc. 17 Stonegate, York.
1886. *ANDERSON, WILLIAM, D.C.L., M.Inst.C.E. Lesney House, Erith, Kent.
1880. ‡Andrew, Mrs. 126 Jamaica-street, Stepney, London, E.
1883. ‡Andrew, Thomas, F.G.S. 18 Southernhay, Exeter.
1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1886. §Andrews, William. Gosford Lodge, Coventry.
1883. §Anelay, Miss M. Mabel. Girton College, Cambridge.
1877. §ANGELL, JOHN, F.C.S. 81 Ducie-grove, Oxford-street Manchester.

Year of Election.

1886. §Annan, John. Wolverhampton.
1886. ‡Ansell, Joseph. 38 Waterloo-street, Birmingham.
1878. ‡Anson, Frederick H. 15 Dean's-yard, Westminster, S.W.
Anthony, John, M.D. 6 Greenfield-crescent, Edgbaston, Birmingham.
1890. §Antrobus, J. Coutts. Eaton Hall, Congleton.
1886. §Arblaster, Edmund, M.A. The Grammar School, Carlisle.
1870. ‡Archer, Francis. 14 Cook-street, Liverpool.
1874. ‡Archer, William, F.R.S., M.R.I.A. 11 South Frederick-street, Dublin.
1884. **Archibald, E. Douglas. Grosvenor House, Tunbridge Wells.*
1851. ‡ARGYLL, His Grace the Duke of, K.G., K.T., D.C.L., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London, W.; and Inverary, Argyllshire.
1884. §Arlidge, John Thomas, M.D., B.A. The High Grove, Stoke-upon-Trent.
1883. §Armistead, Richard. 28 Chambres-road, Southport.
1883. *Armistead, William. 15 Rupert-street, Compton-road, Wolverhampton.
1887. ‡Armitage, Benjamin. Chomlea, Pendleton, Manchester.
1861. ‡Armitage, William. 95 Portland-street, Manchester.
1867. *Armitstead, George. Errol Park, Errol, N.B.
1857. *ARMSTRONG, The Right Hon. Lord, C.B., LL.D., D.C.L., F.R.S. Jesmond Dene, Newcastle-upon-Tyne.
1879. *Armstrong, Sir Alexander, K.C.B., M.D., LL.D., F.R.S., F.R.G.S. The Albany, London, W.
1886. ‡Armstrong, George Frederick, M.A., F.R.S.E., F.G.S., Regius Professor of Engineering in the University of Edinburgh. The University, Edinburgh.
1873. §ARMSTRONG, HENRY E., Ph.D., F.R.S., Sec.C.S., Professor of Chemistry in the City and Guilds of London Institute, Central Institution, Exhibition-road, London, S.W. 55 Granville Park, Lewisham, S.E.
1876. ‡Armstrong, James. Bay Ridge, Long Island, New York, U.S.A.
1889. ‡Armstrong, John A. 32 Eldon-street, Newcastle-upon-Tyne.
1884. ‡Armstrong, Robert B. Junior Carlton Club, Pall Mall, London, S.W.
Armstrong, Thomas. Higher Broughton, Manchester.
1889. ‡Armstrong, Thomas John. 14 Hawthorn-terrace, Newcastle-upon-Tyne.
1870. ‡Arnott, Thomas Reid. Bramshill, Harlesden Green, London, N.W.
1853. *Arthur, Rev. William, M.A. Clapham Common, London, S.W.
1886. ‡Ascough, Jesse. Patent Borax Company, Newmarket-street, Birmingham.
1870. *Ash, Dr. T. Linnington. Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.
1889. §Ashley, Howard M. Ferrybridge, Normanton.
1873. ‡Ashton, John. Gorse Bank House, Windsor-road, Oldham.
ASHTON, THOMAS, J.P. Ford Bank, Didsbury, Manchester.
1887. ‡Ashton, Thomas Gair, M.A. 36 Charlotte-street, Manchester.
1866. ‡Ashwell, Henry. Woodthorpe, Nottingham.
*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
1887. ‡Ashworth, Mrs. Harriet. Thorne Bank, Heaton Moor, near Stockport.
Ashworth, Henry. Turton, near Bolton.
1888. *Ashworth, J. J. 39 Spring-gardens, Manchester.

Year of Election.

1890. §Ashworth, J. Reginald. 20 King-street, Rochdale.
1887. §Ashworth, John Wallwork. Thorne Bank, Heaton Moor, near Stockport.
1887. ‡Aspland, Arthur P. Werneth Lodge, Gee Cross, near Manchester.
1875. *Aspland, W. Gaskell. 93 Fellows-road, London, N.W.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Theodore. 11 New-square, Lincoln's Inn, London, W.C.
1872. *ATCHISON, ARTHUR T., M.A. 60 Warwick-road, Earl's Court, London, S.W.
1887. §Atkinson, Rev. C. Chetwynd, B.A. Goresfield, Ashton-on-Mersey.
1865. *ATKINSON, EDMUND, Ph.D., F.C.S. Portesbery Hill, Camberley, Surrey.
1884. ‡Atkinson, Edward. Brookline, Massachusetts, Boston, U.S.A.
1863. *Atkinson, G. Clayton. 21 Windsor-terrace, Newcastle-on-Tyne.
1861. ‡Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
1858. *Atkinson, John Hastings. 12 East Parade, Leeds.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1881. ‡ATKINSON, ROBERT WILLIAM, F.C.S. 44 Loudoun-square, Cardiff.
1863. *ATTFIELD, Professor J., M.A., Ph.D., F.R.S., F.C.S. 17 Bloomsbury-square, London, W.C.
1884. ‡Auchincloss, W. S. 209 Church-street, Philadelphia, U.S.A.
1886. ‡Aulton, A. D., M.D. Walsall.
1860. *Austin-Gourlay, Rev. William E. C., M.A. The Gables, Winchester.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1881. ‡AXON, W. E. A. Fern Bank, Higher Broughton, Manchester.
1888. ‡Ayre, Rev. J. W., M.A. 30 Green-street, Grosvenor-square, London, W.
1877. *AYRTON, W. E., F.R.S., Professor of Applied Physics in the City and Guilds of London Institute, Central Institution, Exhibition-road, London, S.W.

*BABINGTON, CHARLES CARDALE, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.
1884. ‡Baby, The Hon. G. Montreal, Canada.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's Wolsingham, near Darlington.
1887. *Bacon, Thomas Walter. 4 Lyndhurst-road, Hampstead, London, N.W.
1887. ‡Baddeley, John. 1 Charlotte-street, Manchester.
1881. ‡Baden-Powell, Sir George S., K.C.M.G., M.A., M.P., F.R.A.S., F.S.S. 8 St. George's-place, Hyde Park, London, S.W.
1877. ‡Badock, W. F. Badminton House, Clifton Park, Bristol.
1883. ‡*Bagrual, P. H. St. Stephen's Club, Westminster, S.W.*
1883. ‡Baildon, Dr. 65 Manchester-road, Southport.
1883. *Bailey, Charles, F.L.S. Ashfield, College-road, Whalley Range, Manchester.
1870. ‡Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1887. *Bailey, G. H., D.Sc., Ph.D. Owens College, Manchester.
1878. ‡*Bailey, John. The Laurels, Wittington, near Hereford.*
1865. ‡Bailey, Samuel, F.G.S. Ashley House, Calthorpe-road, Edgbaston, Birmingham.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1887. ‡Bailey, W. H. Summerfield, Eccles Old-road, Manchester.

Year of Election.

1866. ‡Baillon, Andrew. British Consulate, Brest.
1878. ‡Baily, Walter. 176 Haverstock-hill, London, N.W.
1885. ‡BAIN, ALEXANDER, M.A., LL.D., Rector of the University of Aberdeen. Ferryhill Lodge, Aberdeen.
1873. ‡Bain, Sir James. 3 Park-terrace, Glasgow.
1885. ‡Bain, William N. Collingwood, Pollokshields, Glasgow.
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1882. *BAKER, Sir BENJAMIN, K.C.M.G., LL.D., F.R.S., M.Inst.C.E. 2 Queen Square-place, Westminster, S.W.
1866. ‡Baker, Francis B. Sherwood-street, Nottingham.
1886. ‡Baker, Harry. 262 Plymouth-grove, Manchester.
1861. *Baker, John. The Gables, Buxton.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1863. ‡Baker, William. 6 Taptonville, Sheffield.
1875. *Baker, W. Mills. The Holmes, Stoke Bishop, Bristol.
1875. ‡BAKER, W. PROCTOR. Brislington, Bristol.
1881. ‡Baldwin, Rev. G. W. de Courcy, M.A. Lord Mayor's Walk, York.
1884. ‡Balete, Professor E. Polytechnic School, Montreal, Canada.
1871. ‡Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
1875. ‡BALFOUR, ISAAC BAYLEY, D.Sc., M.D., F.R.S.L. & E., F.L.S., Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1878. *Ball, Charles Bent, M.D. 16 Lower Fitzwilliam-street, Dublin.
1866. *BALL, Sir ROBERT STAWELL, LL.D., F.R.S., F.R.A.S., Andrews Professor of Astronomy in the University of Dublin, and Astronomer Royal for Ireland. The Observatory, Dunsink, Co. Dublin.
1878. ‡BALL, VALENTINE, C.B., M.A., LL.D., F.R.S., F.G.S., Director of the Museum of Science and Art, Dublin.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1886. §Ballantyne, J. W., M.B. 50 Queen-street, Edinburgh.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1890. §Bamford, Harry, B.Sc. The Owens College, Manchester.
1882. ‡Bance, Major Edward. Limewood, The Avenue, Southampton.
1870. ‡BANISTER, Rev. WILLIAM, B.A. St. James's Mount, Liverpool.
1884. ‡Bannatyne, Hon. A. G. Winnipeg, Canada.
1884. ‡Barbeau, E. J. Montreal, Canada.
1866. ‡Barber, John. Long-row, Nottingham.
1884. ‡Barber, Rev. S. F. West Raynham Rectory, Swaffham, Norfolk.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1876. *Barclay, Robert. 21 Park-terrace, Glasgow.
1887. *Barclay, Robert. Springfield, Kersal, Manchester.
1886. ‡Barclay, Thomas. 17 Bull-street, Birmingham.
1868. *Barclay, W. L. 54 Lombard-street, London, E.C.
1881. ‡Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. D. Above Bar, Southampton.
1863. *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.
1886. ‡Barham, F. F. Bank of England, Birmingham.
1890. §Barker, Alfred, M.A. 3 Grove-road, Leeds.

Year of Election.

1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.
1879. ‡Barker, Elliott. 2 High-street, Sheffield.
1882. *Barker, Miss J. M. Hexham House, Hexham.
1879. *Barker, Rev. Philip C., M.A., LL.B. Boroughbridge Vicarage, Bridgwater.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. ‡BARKLY, Sir HENRY, G.C.M.G., K.C.B., F.R.S., F.R.G.S. 1 Bina-gardens, South Kensington, London, S.W.
1889. ‡Barkus, Dr. B. 3 Jesmond-terrace, Newcastle-upon-Tyne.
1886. ‡Barling, Gilbert. 85 Edmund-street, Edgbaston, Birmingham.
1873. ‡Barlow, Crawford, B.A. 2 Old Palace-yard, Westminster, S.W.
1889. §Barlow, H. W. L. Holly Bank, Croftsbank-road, Urmston, near Manchester.
1883. ‡Barlow, J. J. 37 Park-street, Southport.
1878. ‡Barlow, John, M.D., Professor of Physiology in Anderson's College, Glasgow.
1883. ‡Barlow, John R. Greenthorne, near Bolton.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
1885. ‡Barlow, William. Hillfield, Muswell Hill, London, N.
1873. ‡BARLOW, WILLIAM HENRY, F.R.S., M.Inst.C.E. 2 Old Palace-yard, Westminster, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1881. ‡Barnard, William, LL.B. Harlow, Essex.
1889. ‡Barnes, J. W. Bank, Durham.
1868. §Barnes, Richard H. Heatherlands, Parkstone, Dorset.
1884. ‡Barnett, J. D. Port Hope, Ontario, Canada.
1886. ‡Barnsley, Charles H. 32 Duchess-road, Edgbaston, Birmingham.
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E. The University, Glasgow.
1890. §Barr, Frederick H. 4 South-parade, Leeds.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1883. ‡Barrett, John Chalk. Errismore, Birkdale, Southport.
1883. ‡Barrett, Mrs. J. C. Errismore, Birkdale, Southport.
1860. ‡Barrett, T. B. 20 Victoria-terrace, Welshpool, Montgomery.
1872. *BARRETT, W. F., F.R.S.E., M.R.I.A., Professor of Physics in the Royal College of Science, Dublin.
1883. ‡Barrett, William Scott. Winton Lodge, Crosby, near Liverpool.
1887. §Barrington, Miss Amy. Fassaroe, Bray, Co. Wicklow.
1874. *BARRINGTON, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1885. *Barron, Frederick Cadogan, M.Inst.C.E. Nervion, Beckenham-grove, Shortlands, Kent.
1881. §BARRON, G. B., M.D. Summerseat, Southport.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1886. ‡Barrow, George William. Baldraud, Lancaster.
1886. ‡Barrow, Richard Bradbury. Lawn House, 13 Ompton-road, Edgbaston, Birmingham.
1886. ‡Barrows, Joseph. The Poplars, Yardley, near Birmingham.
1886. ‡Barrows, Joseph, jun. Ferndale, Harborne-road, Edgbaston, Birmingham.
1858. ‡BARRY, Right Rev. ALFRED, D.D., D.C.L. Knapdale, Upper Tooting, Surrey.
1862. *BARRY, CHARLES. 15 Pembridge-square, London, W.

Year of Election.

1883. ‡Barry, Charles E. 15 Pembridge-square, London, W.
1875. ‡Barry, John Wolfe. 23 Delahay-street, Westminster, S.W
1881. ‡Barry, J. W. Duncombe-place, York.
1884. *Barstow, Miss Frances. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1858. *Bartholomew, Charles. Castle Hill House, Ealing, Middlesex, W.
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Headingley, Leeds.
1884. ‡Bartlett, James Herbert. 148 Mansfield-street, Montreal, Canada.
1873. ‡Bartley, George C. T., M.P. St. Margaret's House, Victoria-street, London, S.W.
1884. ‡Barton, H. M. Foster-place, Dublin.
1852. ‡Barton, James. Farndreg, Dundalk.
1887. ‡Bartrum, John S. 13 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1882. *Basing, The Right Hon. Lord, F.R.S. 74 St. George's-square, London, S.W.
1876. ‡Bassano, Alexander. 12 Montagu-place, London, W.
1876. ‡Bassano, Clement. Jesus College, Cambridge.
1888. *Basset, A. B., M.A., F.R.S. Chapel Place Mansions, 322 Oxford-street, London, W.
1866. *Bassett, Henry. 26 Belitha-villas, Barnsbury, London, N.
1889. §Bastable, Professor C. F., M.A., F.S.S. 74 Kenilworth-square, Rathgar, Co. Dublin.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡Bastian, H. Charlton, M.A., M.D., F.R.S., F.L.S., Professor of the Principles and Practice of Medicine in University College, London. 8a Manchester-square, London, W.
1889. §Batalha-Reis, J. Portuguese Consulate, Newcastle-upon-Tyne.
1883. ‡Bateman, A. E. Board of Trade, London, S.W.
1873. *Bateman, Daniel. Wissahickon, Philadelphia, U.S.A.
1868. ‡Bateman, Frederick, M.D. Upper St. Giles's-street, Norwich.
Bateman, James, M.A., F.R.S., F.R.G.S., F.L.S. Home House, Worthing.
1889. ‡Bates, C. J. Heddon, Wylam, Northumberland.
1864. ‡Bates, Henry Walter, F.R.S., F.L.S., Assist.-Sec. R.G.S. 1 Savile-row, London, W.
1884. ‡Bateson, William, B.A. St. John's College, Cambridge.
1851. ‡Bath and Wells, The Right Rev. Lord Arthur Hervey, Lord Bishop of, D.D. The Palace, Wells, Somerset.
1881. *Bather, Francis Arthur, M.A., F.G.S. 207 Harrow-road, London, W.
1836. ‡Batten, Edmund Chisholm. 25 Thurloe-square, London, S.W.
1863. §Bauerman, H., F.G.S. 9 Hazlebourne-gardens, Cavendish-road, Balham, London, S.W.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1868. ‡*Bayes, William, M.D. 58 Brook-street, London, W.*
Bayly, John. Seven Trees, Plymouth.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E. 3 Church-walk, Oxford.
1887. ‡Baynton, Alfred. 28 Gilda Brook Park, Eccles, Manchester.
1883. *Bazley, Gardner. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Sir Thomas Sebastian, Bart., M.A. Hatherop Castle, Fairford, Gloucestershire.
1886. ‡Beale, C. Calle Progress No. 83, Rosario de Santa Fé, Argentine Republic.

Year of
Election.

1886. ‡Beale, Charles G. Maple Bank, Edgbaston, Birmingham.
1860. *BEALE, LIONEL S., M.B., F.R.S., Professor of the Principles and Practice of Medicine in King's College, London. 61 Grosvenor-street, London, W.
1882. §Beamish, Major A. W., R.E. 28 Grosvenor-road, London, S.W.
1884. ‡Beamish, G. H. M. Prison, Liverpool.
1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.
1883. ‡Beard, Mrs. 13 South-hill-road, Toxteth Park, Liverpool.
1889. §Beare, Professor T. Hudson, F.R.S.E. University College, London, W.C.
1887. ‡Beaton, John, M.A. 219 Upper Brook-street, Chorlton-on-Medlock, Manchester.
1842. *Beatson, William. Ash Mount, Rotherham.
1888. ‡Beatson, W. B., M.D. 11 Cavendish-place, Bath.
1889. ‡Beattie, John. 5 Summerhill-grove, Newcastle-upon-Tyne.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.R.M.S., F.S.S. 18 Piccadilly, London, W.
1886. ‡Beaugrand, M. H. Montreal.
1861. *Beaumont, Rev. Thomas George. Oakley Lodge, Leamington.
1887. *Beaumont, W. J. 10 Burlington-street, Bath.
1885. §Beaumont, W. W. Melford, Palace-road, Tulse Hill, London, S.W.
1871. *Beazley, Lieut.-Colonel George G. 74 Redcliffe-square, London, S.W.
1859. *Beck, Joseph, F.R.A.S. 68 Cornhill, London, E.C.
1887. *Beckett, John Hampden. Wilmslow Park, Wilmslow, Manchester.
1885. §BEDDARD, FRANK E., M.A., F.Z.S., Prosector to the Zoological Society of London. Society's Gardens, Regent's Park, London, N.W.
1866. ‡Beddard, James. Derby-road, Nottingham.
1870. §BEDDOE, JOHN, M.D., F.R.S. The Manor House, Clifton, Bristol.
1858. §Bedford, James. Woodhouse Cliff, near Leeds.
1890. §Bedford, James E., F.G.S. Clifton-villas, Cardigan-road, Leeds.
1878. ‡BEDSON, P. PHILLIPS, D.Sc., F.C.S., Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.
1884. ‡Beers, W. G., M.D. 34 Beaver Hall-terrace, Montreal, Canada.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1873. ‡Bell, Asahel P. 32 St. Anne's-street, Manchester.
1871. §Bell, Charles B. 6 Spring-bank, Hull.
1884. ‡Bell, Charles Napier. Winnipeg, Canada.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.
1880. §Bell, Henry Oswin. 13 Northumberland-terrace, Tynemouth.
1862. *BELL, Sir ISAAC LOWTHIAN, Bart., F.R.S., F.C.S., M.Inst.C.E. Rounton Grange, Northallerton.
1875. ‡Bell, James, C.B., D.Sc., Ph.D., F.R.S., F.C.S. The Laboratory, Somerset House, London, W.C.
1871. *BELL, J. CARTER, F.C.S. Bankfield, The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. Dalton Lees, Huddersfield.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1876. ‡Bell, R. Bruce, M.Inst.C.E. 203 St. Vincent-street, Glasgow.
1863. **Bell, Thomas. Oakwood, Epping.*
1867. ‡Bell, Thomas. Belmont, Dundee.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.

Year of Election.

1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1882. ‡Bellingham, William. 15 Killieser-avenue, Telford Park, Streatham Hill, London, S.W.
1884. ‡Bemrose, Joseph. 15 Plateau-street, Montreal, Canada.
1886. §Benger, Frederick Baden, F.I.C., F.C.S. 7 Exchange-street, Manchester.
1885. ‡Benham, William Blaxland, D.Sc. University College, London, W.C.
1870. ‡Bennett, Alfred W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1836. §Bennett, Henry. Bedminster, Bristol.
1887. ‡Bennett, James M. St. Mungo Chemical Company, Ruckhill, Glasgow.
1881. §Bennett, John R. 16 West Park, Clifton, Bristol.
1883. *Bennett, Laurence Henry. Bedminster, Bristol.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishopshill Junior, York.
1870. *Bennett, William. Oak Hill Park, Old Swan, near Liverpool.
1887. ‡Bennion, James A., M.A. 1 St. James'-square, Manchester.
1889. ‡Benson, John G. 12 Grey-street, Newcastle-upon-Tyne.
1848. ‡Benson, Starling. Gloucester-place, Swansea.
1863. ‡Benson, William. Fourstones Court, Newcastle-upon-Tyne.
1885. *Bent, J. Theodore. 13 Great Cumberland-place, London, W.
1884. ‡Bentham, William. 724 Sherbrooke-street, Montreal, Canada.
1863. ‡Bentley, Robert, F.L.S. 38 Penywern-road, Earl's Court, London, S.W.
1886. ‡*Benton, William Elijah. Littleworth House, Hednesford, Staffordshire.*
1876. ‡Bergius, Walter C. 9 Loudon-terrace, Hillhead, Glasgow.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1886. ‡Bernard, W. Leigh. Calgary, Canada.
1887. §Berry, William. Parklands, Bowdon, Cheshire.
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1865. *Bessemer, Sir Henry, F.R.S. Denmark Hill, London, S.E.
1882. *Bessemer, Henry, jun. Town Hill Park, West End, Southampton.
1890. §Best, William Woodham. 31 Lyddon-terrace, Leeds.
1883. ‡Betley, Ralph, F.G.S. Mining School, Wigan.
1876. *Bettany, G. T., M.A., B.Sc., F.L.S., F.R.M.S. 33 Oakhurst-grove, East Dulwich-road, London, S.E.
1883. ‡Bettany, Mrs. 33 Oakhurst-grove, East Dulwich-road, London, S.E.
1880. *Bevan, Rev. James Oliver, M.A., F.G.S. The Vicarage, Vowchurch, Hereford.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1885. ‡Beveridge, R. Beath Villa, Ferryhill, Aberdeen.
1874. *Bevington, James B. Merle Wood, Sevenoaks.
1890. §Bevington, Miss Mary E. The Elms, Bickley Park, Kent.
1863. ‡Bewick, Thomas John, F.G.S. Suffolk House, Laurence Pountney Hill, London, E.C.
1844. *Bickerdike, Rev. John, M.A. Shireshead Vicarage, Garstang.
1886. §Bickersteth, The Very Rev. E., D.D., Dean of Lichfield. The Deanery, Lichfield.
1870. ‡Bickerton, A.W., F.C.S. Christchurch, Canterbury, New Zealand.
1888. *Bidder, George Parker. Trinity College, Cambridge.
1885. *Bidwell, Shelford, M.A., LL.B., F.R.S. Riverstone Lodge, Southfields, Wandsworth, Surrey, S.W.

Year of
Election.

1882. §Biggs, C. H. W., F.C.S. Glebe Lodge, Champion Hill, London, S.E.
1886. ‡Bindloss, G. F. Carnforth, Brondesbury Park, London, N.W.
1887. *Bindloss, James B. Elm Bank, Eccles, Manchester.
1884. *Bingham, John E. Electric Works, Sheffield.
1881. §Binnie, Alexander R., M.Inst.C.E., F.G.S. London County Council, Spring-gardens, London, S.W.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
1880. ‡Bird, Henry, F.C.S. South Down, near Devonport.
1866. **Birkin, Richard. Aspley Hall, near Nottingham.*
1888. *Birley, Miss Caroline. Seedley-terrace, Pendleton, Manchester.
1887. *Birley, H. K. 13 Hyde-road, Ardwick, Manchester.
1871. *Bischof, Gustav. 4 Hart-street, Bloomsbury, London, W.C.
1883. ‡Bishop, John le Marchant. 100 Mosley-street, Manchester.
1885. ‡Bissett, J. P. Wyndem, Banchory, N.B.
1886. *Bixby, Captain W. H. War Department, Washington, U.S.A.
1884. ‡Black, Francis, F.R.G.S. 6 North Bridge, Edinburgh.
1889. ‡Black, W. 1 Lovaine-place, Newcastle-upon-Tyne.
1889. §Black, William. 12 Romulus-terrace, Gateshead.
1881. ‡Black, Surgeon-Major William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1834. Blackburn, Bewicke. Calverley Park, Tunbridge Wells.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
1884. ‡Blackburn, Robert. New Edinburgh, Ontario, Canada.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1859. ‡Blackie, John S., M.A., Emeritus Professor of Greek in the Unisity of Edinburgh. 9 Douglas-crescent, Edinburgh.
1876. ‡Blackie, Robert. 7 Great Western-terrace, Glasgow.
1855. *Blackie, W. G., Ph.D., F.R.G.S. 17 Stanhope-street, Glasgow.
1884. ‡Blacklock, Frederick W. 25 St. Famille-street, Montreal, Canada.
1883. ‡Blacklock, Mrs. Sea View, Lord-street, Southport.
1884. ‡*Blaikie, James, M.A. 14 Viewforth-place, Edinburgh.*
1888. ‡Blaine, R. S., J.P. Summerhill Park, Bath.
1883. ‡Blair, Mrs. Oakshaw, Paisley.
1863. ‡Blake, C. Carter, D.Sc. 4 Charlton-street, Fitzroy-square, London, W.
1886. ‡Blake, Dr. James. San Francisco, California.
1849. *Blake, Henry Wollaston, M.A., F.R.S., F.R.G.S. 8 Devonshire-place, Portland-place, London, W.
1883. *Blake, Rev. J. F., M.A., F.G.S. 40 Loudoun-road, London, N.W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1878. ‡Blakeney, Rev. Canon, M.A., D.D. The Vicarage, Sheffield.
1886. ‡Blakie, John. The Bridge House, Newcastle, Staffordshire.
1861. §Blakiston, Matthew, F.R.G.S. Free Hills, Burledon, Hants.
1887. §Blamires, George. Cleckheaton.
1881. §Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1869. ‡Blanford, W. T., LL.D., F.R.S., F.G.S., F.R.G.S. 72 Bedford-gardens, Campden Hill, London, W.
1887. *Bles, A. J. S. Moor End, Kersal, Manchester.
1887. *Bles, Edward J. Moor End, Kersal, Manchester.
1887. ‡Bles, Marcus S. The Beeches, Broughton Park, Manchester.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1869. *Blomefield, Rev. Leonard, M.A., F.L.S., F.G.S. 19 Belmont, Bath.

Year of Election.

1880. §Bloxam, G. W., M.A., F.L.S. 3 Hanover-square, London, W.
1888. §Bloxsom, M. 73 Clarendon-road, Crumpsall, Manchester.
1883. ‡Blumberg, Dr. 65 Hoghton-street, Southport.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Captain Richard. Bretlands, Chertsey, Surrey.
1885. ‡Blyth, James, M.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College, Glasgow.
Blyth, B. Hall. 135 George-street, Edinburgh.
1883. ‡Blyth, Miss Phœbe. 3 South Mansion House-road, Edinburgh.
1867. ‡Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1887. ‡Blythe, William S. 65 Mosley-street, Manchester.
1870. ‡Boardman, Edward. Queen-street, Norwich.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1889. §Bodmer, G. R., Assoc.M.Inst.C.E. 10 Westwick-gardens, West Kensington Park, London, W.
1884. ‡Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1887. *Boissevain, Gideon Maria. 4 Jesselschade-straat, Amsterdam.
1881. ‡Bojanowski, Dr. Victor de. 27 Finsbury-circus, London, E.C.
1876. ‡Bolton, J. C. Carbrook, Stirling.
Bond, Henry John Hayes, M.D. Cambridge.
1883. §Bonney, Frederic, F.R.G.S. Colton House, Rugeley, Staffordshire.
1883. §Bonney, Miss S. 23 Denning-road, Hampstead, London, N.W.
1871. *Bonney, Rev. Thomas George, D.Sc., LL.D., F.R.S., F.S.A., F.G.S., Professor of Geology in University College, London. 23 Denning-road, Hampstead, London, N.W.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1888. §Boon, William. Coventry.
1890. *Booth, Charles, F.S.S. 2 Talbot-court, Gracechurch-street, London, E.C.
1883. ‡Booth, James. Hazelhurst House, Turton.
1883. ‡Booth, Richard. 4 Stone-buildings, Lincoln's Inn, London, W.C.
1876. ‡Booth, Rev. William H. St. Germain's-place, Blackheath, London, S.E.
1883. ‡Boothroyd, Benjamin. Rawlinson-road, Southport.
1876. *Borland, William. 260 West George-street, Glasgow.
1882. §Borns, Henry, Ph.D., F.C.S. Friedheim, Springfield-road, Wimbledon, Surrey.
1376. *Bosanquet, R. H. M., M.A., F.R.S., F.R.A.S.,. FC.S., New University Club, St. James's-street, London, S.W.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1881. §Bothamley, Charles H., F.C.S. Yorkshire College, Leeds.
1867. §Botly, William, F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1887. ‡Bott, Dr. Owens College, Manchester.
1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1887. ‡Bottomley, James, D.Sc., B.A. 220 Lower Broughton-road, Manchester.
1871. *Bottomley, James Thomson, M.A., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1876. ‡Bottomley, William, jun. 6 Rokeley-terrace, Hillhead, Glasgow.
1890. §Boulnois, Henry Percy, M.Inst.C.E. Municipal Offices, Liverpool.
1883. ‡Bourdas, Isaiah. Dunoon House, Clapham Common, London, S.W.

Year of Election.

1883. ‡BOURNE, A. G., D.Sc., F.L.S., Professor of Zoology in the Presidency College, Madras.
1889. ‡Bourne, R. H. Fox. 41 Priory-road, Bedford Park, London, W.
1866. §BOURNE, STEPHEN, F.S.S. Abberley, Wallington, Surrey.
1890. §Bousfield, C. E. 55 Clarendon-road, Leeds.
1884. ‡BOVEY, HENRY T., M.A., Professor of Civil Engineering and Applied Mechanics in McGill University, Montreal. Ontario-avenue, Montreal, Canada.
1888. ‡Bowden, Rev. G. New Kingswood School, Lansdown, Bath.
1870. ‡Bower, Anthony. Bowersdale, Seaforth, Liverpool.
1881. *BOWER, F. O., F.L.S., Professor of Botany in the University of Glasgow.
1867. ‡Bower, Dr. John. Perth.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1886. ‡Bowlby, Rev. Canon. 101 Newhall-street, Birmingham.
1884. ‡Bowley, Edwin. Burnt Ash Hill, Lee, Kent.
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1865. §Bowman, F. H., D.Sc., F.R.S.E. Halifax, Yorkshire.
BOWMAN, Sir WILLIAM, Bart., M.D., LL.D., F.R.S., F.R.C.S. 5 Clifford-street, London, W.
1887. §Box, Alfred M. Scissett, near Huddersfield.
1863. ‡Boyd, Edward Fenwick. Moor House, near Durham.
1884. *Boyd, M. A., M.D. 30 Merrion-square, Dublin.
1887. ‡Boyd, Robert. Manor House, Didsbury, Manchester.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡BOYLE, The Very Rev. G. D., M.A., Dean of Salisbury. The Deanery, Salisbury.
1884. *Boyle, R. Vicars, C.S.I. Care of Messrs. Grindlay & Co., 55 Parliament-street, London, S.W.
1872. *BRABROOK, E. W., F.S.A., V.P.A.I. 28 Abingdon-street, Westminster, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1884. *Brace, W. H., M.D. 7 Queen's Gate-terrace, London, S.W.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
1863. ‡BRADY, GEORGE S., M.D., LL.D., F.R.S., F.L.S., Professor of Natural History in the Durham College of Science, Newcastle-on-Tyne. 2 Mowbray-villas, Sunderland.
1880. *Brady, Rev. Nicholas, M.A. Rainham Hall, Rainham, Romford, Essex.
1864. ‡BRAHAM, PHILIP, F.C.S. Bath.
1870. ‡Braidwood, Dr. 35 Park-road South, Birkenhead.
1888. §Braikenridge, W. J., J.P. 16 Royal-crescent, Bath.
1879. ‡Bramley, Herbert. 6 Paradise-square, Sheffield.
1865. §BRAMWELL, Sir FREDERICK J., Bart., D.C.L., F.R.S., M.Inst.C.E 5 Great George-street, London, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. Dickleburgh Rectory, Scole, Norfolk.
1890. §Branson, F. W. Commercial-street, Leeds.
1885. *Bratby, W. Pott-street, Ancoats, Manchester.
1890. *Bray, George. Belmont, Headingley, Leeds.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1877. ‡Brent, Francis. 19 Clarendon-place, Plymouth.
1882. *Bretherton, C. E. 1 Garden-court, Temple, London, E.C.
1881. *Brett, Alfred Thomas, M.D. Watford House, Watford.

Year of Election.

1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1875. ‡Briant, T. Hampton Wick, Kingston-on-Thames.
1886. ‡Bridge, T. W., M.A., Professor of Zoology in the Mason Science College, Birmingham.
1884. ‡Bridges, C. J. Winnipeg, Canada.
1870. *Bridson, Joseph R. Sawrey, Windermere.
1887. ‡Brierley, John, J.P. The Clough, Whitefield, Manchester.
1870. ‡Brierley, Joseph. New Market-street, Blackburn.
1886. ‡Brierley, Leonard. Somerset-road, Edgbaston, Birmingham.
1879. ‡Brierley, Morgan. Denshaw House, Saddleworth.
1870. *Brigg, John. Broomfield, Keighley, Yorkshire.
1889. ‡Brigg, T. H. The Grange, Weston, near Otley, Yorkshire.
1890. §Brigg, W. A. Kildwick Hall, near Keighley, Yorkshire.
1866. *Briggs, Arthur. Cragg Royd, Rawdon, near Leeds.
1870. ‡Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
1868. ‡Brine, Captain Lindesay, F.R.G.S. United Service Club, Pall Mall, London, S.W.
1884. ‡Brisette, M. H. 424 St. Paul-street, Montreal, Canada.
1879. ‡Brittain, Frederick. Taptonville-crescent, Sheffield.
1879. *Brittain, W. H., J.P. Storth Oaks, Ranmoor, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, London, S.W.
1884. *Brittle, John R., M.Inst.C.E., F.R.S.E. Farad Villa, Vanbrugh Hill, Blackheath, London, S.E.
1859. *Brodhurst, Bernard Edward, F.R.C.S., F.L.S. 20 Grosvenor-street, Grosvenor-square, London, W.
1883. *Brodie, David, M.D. 12 Patten-road, Wandsworth Common, S.W.
1865. ‡Brodie, Rev. Peter Bellinger, M.A., F.G.S. Rowington Vicarage, near Warwick.
1884. ‡Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1883. *Brodie-Hall, Miss W. L. The Gore, Eastbourne.
1878. *Brook, George, F.L.S. The University, Edinburgh.
1881. §Brook, Robert G. Rowen-street, St. Helens, Lancashire.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Ven. Archdeacon J. Ingham. The Vicarage, Halifax.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1888. ‡Brooke, Rev. Canon R. E., M.A. 14 Marlborough-buildings, Bath.
1878. ‡Brooke, Sir Victor, Bart., F.L.S. Colebrook, Brookeborough, Co. Fermanagh.
1887. §Brooks, James Howard. Green Bank, Monton, Eccles, Manchester.
1863. ‡Brooks, John Crosse. 14 Lovaine-place, Newcastle-on-Tyne.
1887. ‡Brooks, S. H. Slade House, Levenshulme, Manchester.
1846. *Brooks, Sir Thomas, Bart. Cranshaw Hall, Rawtenstall, Manchester.
1887. *Bros, W. Law. Sidcup, Kent.
1883. §Brotherton, E. A. Fern Cliffe, Ilkley, Leeds.
1886. §Brough, Joseph. University College, Aberystwith.
1885. *Browett, Alfred. 14 Dean-street, Birmingham.
1863. *Brown, Alexander Crum, M.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1867. ‡Brown, Charles Gage, M.D., C.M.G. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. 93 Abbey-hill, Edinburgh.

Year of Election.

1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1883. §Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1881. ‡Brown, Frederick D. 26 St. Giles's-street, Oxford.
1887. ‡Brown, George. Cadishead, near Manchester.
1883. ‡Brown, George Dransfield. Henley Villa, Ealing, Middlesex, W.
1884. ‡Brown, Gerald Culmer. Lachute, Quebec, Canada.
1883. ‡Brown, Mrs. H. Bienz. 26 Ferryhill-place, Aberdeen.
1884. ‡Brown, Harry. University College, London, W.C.
1883. ‡Brown, Mrs. Helen. 52 Grange Loan, Edinburgh.
1870. §BROWN, HORACE T., F.R.S., F.C.S. 47 High-street, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1883. ‡Brown, Miss Isabella Spring. 52 Grange Loan, Edinburgh.
1870. *BROWN, Professor J. CAMPBELL, D.Sc., F.C.S. University College, Liverpool.
1876. §Brown, John. Belair, Windsor-avenue, Belfast.
1881. *Brown, John, M.D. 68 Bank-parade, Burnley, Lancashire.
1882. *Brown, John. Swiss Cottage, Park-valley, Nottingham.
1859. ‡Brown, Rev. John Crombie, LL.D., F.L.S. Haddington, N.B.
1882. *Brown, Mrs. Mary. 68 Bank-parade, Burnley, Lancashire.
1886. §Brown R., R.N. Laurel Bank, Barnhill, Perth.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-upon-Tyne.
1871. ‡BROWN, ROBERT, M.A., Ph.D., F.L.S., F.R.G.S. Fersley, Rydal-road, Streatham, London, S.W.
1868. ‡Brown, Samuel, M.Inst.C.E., Government Engineer. Nicosia, Cyprus.
1865. ‡Brown, William. 41A New-street, Birmingham.
1885. ‡Brown, W. A. The Court House, Aberdeen.
1884. ‡Brown, William George. Ivy, Albemarle Co., Virginia, U.S.A.
1863. ‡Browne, Sir Benjamin Chapman, M.Inst.C.E. Westacres, Newcastle-upon-Tyne.
1879. ‡Browne, Sir J. Crichton, M.D., LL.D., F.R.S. L. & E. 7 Cumberland-terrace, Regent's Park, London, N.W.
1866. *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.
1862. *Browne, Robert Clayton, M.A. Sandbrook, Tullow, Co. Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Redcot, Bradbourne, Sevenoaks, Kent.
1865. *Browne, William, M.D. Heath Wood, Leighton Buzzard.
1887. ‡Brownell, T. W. 6 St. James's-square, Manchester.
1865. ‡Browning, John, F.R.A.S. 63 Strand, London, W.C.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1855. ‡Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.
1889. §Bruce, J. Collingwood, LL.D., D.C.L., F.S.A. Framlington-place, Newcastle-upon-Tyne.
1863. *Brunel, H. M. 23 Delahay-street, Westminster, S.W.
1863. ‡Brunel, J. 23 Delahay-street, Westminster, S.W.
1875. *BRUNLEES, Sir JAMES, F.R.S.E., F.G.S., M.Inst.C.E. 5 Victoria-street, Westminster, S.W.
1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.
1868. ‡BRUNTON, T. LAUDER, M.D., D.Sc., F.R.S. 10 Stratford-place, Oxford-street, London, W.
1878. §Brutton, Joseph. Yeovil.
1886. *Bryan, G. H. Trumpington-road, Cambridge.
1884. ‡Bryce, Rev. Professor George. The College, Manitoba, Canada.
1859. ‡*Bryson, William Gillespie. Cullen, Aberdeen.*
1890. §Bubb, Henry. Pendyffryn, near Conway, North Wales.
1871. §BUCHAN, ALEXANDER, M.A., LL.D., F.R.S.E., Sec. Scottish Meteorological Society. 72 Northumberland-street, Edinburgh.

Year of Election.

1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
1885. *Buchan, William Paton. Fairyknowe, Cambuslang, N.B.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. 12 Barnard-road, Birkenhead, Cheshire.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡BUCHANAN, JOHN YOUNG, M.A., F.R.S. L. & E. 10 Moray-place, Edinburgh.
1884. ‡Buchanan, W. Frederick. Winnipeg, Canada.
1883. ‡*Buckland, Miss A. W. 54 Doughty-street, London, W.C.*
1886. *Buckle, Edmund W. 23 Bedford-row, London, W.C.
1864. ‡BUCKLE, Rev. GEORGE, M.A. Wells, Somerset.
1865. *Buckley, Henry. The Upper Boon, Linthurst, near Bromsgrove, Birmingham.
1886. §Buckley, Samuel. 76 Clyde-road, Albert-park, Didsbury.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. Science and Art Department, South Kensington, London, S.W.
1880. ‡Buckney, Thomas, F.R.A.S. 53 Gower-street, London, W.C.
1869. ‡Bucknill, J. C., M.D., F.R.S. East Cliff House, Bournemouth.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1887. ‡Budenberg, C. F., B.Sc. Buckau Villa, Demesne-road, Whalley Range, Manchester.
1875. ‡Budgett, Samuel. Kirton, Albemarle-road, Beckenham, Kent.
1883. ‡Buick, Rev. George R., M.A. Cullybackey, Co. Antrim, Ireland.
1871. ‡Bulloch, Matthew. 4 Bothwell-street, Glasgow.
1881. ‡Bulmer, T. P. Mount-villas, York.
1883. ‡Bulpit, Rev. F. W. Crossens Rectory, Southport.
1865. ‡Bunce, John Mackray. 'Journal' Office, New-street, Birmingham.
1886. §Burbury, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, London, W.C.
1842. *Burd, John. Glen Lodge, Knocknerea, Sligo.
1875. ‡Burder, John, M.D. 7 South-parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, London, W.
1881. ‡Burdett-Coutts, W. L. A. B., M.P. 1 Stratton-street, Piccadilly, London, W.
1884. *Burland, Jeffrey H. 287 University-street, Montreal, Canada.
1888. ‡Burne, H. Holland. 28 Marlborough-buildings, Bath.
1883. *Burne, Colonel Sir Owen Tudor, K.C.S.I., C.I.E., F.R.G.S. 57 Sutherland-gardens, Maida Vale, London, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1885. *Burnett, W. Kendall, M.A. The Grove, Kemnay, Aberdeenshire.
1877. ‡Burns, David. Alston, Carlisle.
1884. §Burns, Professor James Austin. Southern Medical College, Atlanta, Georgia, U.S.A.
1883. ‡Burr, Percy J. 20 Little Britain, London, E.C.
1887. ‡Burroughs, Eggleston, M.D. Snow Hill-buildings, London, E.C.
1881. §Burroughs, S. M. Snow Hill-buildings, London, E.C.
1883. *Burrows, Abraham. Greenhall, Atherton, near Manchester.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1888. ‡Burt, John Mowlem. 3 St. John's-gardens, Kensington, London, W.
1888. ‡Burt, Mrs. 3 St. John's-gardens, Kensington, London, W.
1866. *BURTON, FREDERICK M., F.G.S. Highfield, Gainsborough.
1889. ‡Burton, Rev. R. Lingen. Zetland Club, Saltburn-by-the-Sea.
1887. *Bury, Henry. Trinity College, Cambridge.
1878. ‡BUTCHER, J. G., M.A. 22 Collingham-place, London, S.W.
1884. *Butcher, William Deane, M.R.C.S.Eng. Clydesdale, Windsor.
1884. ‡Butler, Matthew I. Napanee, Ontario, Canada.

Year of Election.

1888. ‡Buttanshaw, Rev. John. 22 St. James's-square, Bath.
1884. *Butterworth, W. Greenhill, Church-lane, Harpurhey, Manchester.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1870. ‡*Buxton, David, Ph.D. 298 Regent-street, London, W.*
1883. ‡Buxton, Miss F. M. Newnham College, Cambridge.
1887. *Buxton, J. H. 'Guardian' Office, Manchester.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1881. ‡Buxton, Sydney. 15 Eaton-place, London, S.W.
1883. ‡Buxton, Rev. Thomas, M.A. 19 Westcliffe-road, Birkdale, Southport.
1872. ‡Buxton, Sir Thomas Fowell, Bart., F.R.G.S. Warlies, Waltham Abbey, Essex.
1854. ‡BYERLEY, ISAAC, F.L.S. Seacombe, Cheshire.
1885. ‡Byres, David. 63 North Bradford, Aberdeen.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. §Byrom, John R. Mere Bank, Fairfield, near Manchester.
1875. ‡Byrom, W. Ascroft, F.G.S. 31 King-street, Wigan.

1889. §Cackett, James Thoburn. 60 Larkspur-terrace, Newcastle-upon-Tyne.
1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1876. ‡Caird, Edward B. 8 Scotland-street, Glasgow.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1875. ‡Caldicott, Rev. J. W., D.D. The Rectory, Shipston-on-Stour.
1886. *Caldwell, William Hay. Birnam, Chaucer-road, Cambridge.
1868. ‡Caley, A. J. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1887. ‡CALLAWAY CHARLES, M.A., D.Sc., F.G.S. Sandon, Wellington, Shropshire.
1854. ‡Calver, Captain E. K., R.N., F.R.S. 23 Park-place East, Sunderland, Durham.
1884. ‡Cameron, Æneas. Yarmouth, Nova Scotia, Canada.
1876. ‡Cameron, Charles, M.D., LL.D., M.P. 1 Huntly-gardens, Glasgow.
1857. ‡CAMERON, Sir CHARLES A., M.D. 15 Pembroke-road, Dublin.
1884. ‡Cameron, James C., M.D. 41 Belmont-park, Montreal, Canada.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1884. ‡Campbell, Archibald H. Toronto, Canada.
1874. *CAMPBELL, Sir GEORGE, K.C.S.I., M.P., D.C.L., F.R.G.S., F.S.S. Southwell House, Southwell-gardens, South Kensington, London, S.W.; and Edenwood, Cupar, Fife.
1883. ‡Campbell, H. J. 81 Kirkstall-road, Talfourd Park, Streatham Hill, S.W.
Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
1876. ‡Campbell, James A., LL.D., M.P. Stracathro House, Brechin.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1862. *CAMPION, Rev. WILLIAM M., D.D. Queen's College, Cambridge.
1882. ‡Candy, F. H. 71 High-street, Southampton.
1890. §Cannan, Edwin, M.A., F.S.S. 24 St. Giles's, Oxford.
1888. ‡Cappel, Sir Albert J. L., K.C.I.E. 14 Harrington-gardens, London, W.
1880. ‡Capper, Robert. Norfolk House, Norfolk-street, Strand, London, W.C.
1883. ‡Capper, Mrs. R. Norfolk House, Norfolk-street, Strand, London, W.C.

Year of Election.

1887. ‡Capstick, John Walton. University College, Dundee.
1873. *CARBUTT, EDWARD HAMER, M.Inst.C.E. 19 Hyde Park-gardens, London, W.
1883. ‡*Carey-Hobson, Mrs. 54 Doughty-street, London, W.C.*
1877. ‡Carkeet, John. 3 St. Andrew's-place, Plymouth.
CARLISLE, The Right Rev. HARVEY GOODWIN, D.D., D.C.L., Lord Bishop of. Carlisle.
1867. ‡Carmichael, David (Engineer). Dundee.
1867. ‡Carmichael, George. 11 Dudhope-terrace, Dundee.
1876. ‡Carmichael, Neil, M.D. 22 South Cumberland-street, Glasgow.
1884. ‡Carnegie, John. Peterborough, Ontario, Canada.
1887. ‡Carpenter, A., M.D. Duppas House, Croydon.
1884. §Carpenter, Louis G. Agricultural College, Fort Collins, Colorado, U.S.A.
1871. *CARPENTER, P. HERBERT, D.Sc., F.R.S. Eton College, Windsor.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1888. *Carpmael, Alfred. 1 Copthall-buildings, London, E.C.
1884. *Carpmael, Charles. Toronto, Canada.
1889. ‡Carr, Cuthbert Ellison. Hedgeley, Alnwick.
1889. §Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. British Museum, London, S.W.
1886. ‡CARSLAKE, J. BARHAM. 30 Westfield-road, Birmingham.
1883. ‡Carson, John. 51 Royal Avenue, Belfast.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1868. ‡Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, F.G.S. Cockerham Hall, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 78 Rodney-street, Liverpool.
1883. ‡Carter, W. C. Manchester and Salford Bank, Southport.
1883. ‡Carter, Mrs. Manchester and Salford Bank, Southport.
1878. *Cartwright, E. Henry. 1 Courtfield-gardens, London, S.W.
1870. §Cartwright, Joshua, M.Inst.C.E., Borough Surveyor. Bury, Lancashire.
1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, London, S.W.
1884. ‡Carver, Mrs. Lynnhurst, Streatham Common, London, S.W.
1883. ‡Carver, James. Garfield House, Elm-avenue, Nottingham.
1887. ‡Casartelli, Rev. L. C., M.A., Ph.D. St. Bede's College, Manchester.
1866. ‡Casella, L. P., F.R.A.S. The Lawns, Highgate, London, N.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 38 Elmfield-terrace, Saville Park, Halifax.
1888. ‡Cater, R. B. Avondale, Henrietta Park, Bath.
1874. ‡Caton, Richard, M.D., Lecturer on Physiology at the Liverpool Medical School. Lea Hall, Gateacre, Liverpool.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1887. §Cawley, George. 'Industries,' 358 Strand, London, W.C.
1886. ‡Cay, Albert. Ashleigh, Westbourne-road, Birmingham.
1860. §CAYLEY, ARTHUR, M.A., D.C.L., LL.D., D.Sc., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1860. ‡CHADWICK, DAVID. The Poplars, Herne Hill, London, S.E.
1883. ‡Chadwick, James Percy. 51 Alexandra-road, Southport.
1859. ‡Chadwick, Robert. Highbank, Manchester.

Year of Election.

1883. ‡Chalk, William. 24 Gloucester-road, Birkdale, Southport.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1883. ‡Chamberlain, George, J.P. Helensholme, Birkdale Park, Southport.
1884. ‡Chamberlain, Montague. St. John, New Brunswick, Canada.
1883. ‡CHAMBERS, CHARLES, F.R.S. Colába Observatory, Bombay.
1883. ‡Chambers, Mrs. Colába Observatory, Bombay.
1883. ‡Chambers, Charles, jun., Assoc.M.Inst.C.E. Colába Observatory, Bombay.
1842. Chambers, George. High Green, Sheffield.
1868. ‡Chambers, W. O. Lowestoft, Suffolk.
*Champney, Henry Nelson. 4 New-street, York.
1881. *Champney, John E. Woodlands, Halifax.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. 51 Prince's-gate, London, S.W.
1886. *Chance, John Horner. 40 Augustus-road, Edgbaston, Birmingham.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1888. ‡Chandler, S. Whitty, B.A. Sherborne, Dorset.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Hill End, Mottram, Manchester.
1889. ‡Chapman, L. H. 147 Park-road, Newcastle-upon-Tyne.
1884. ‡Chapman, Professor. University College, Toronto, Canada.
1877. §Chapman, T. Algernon, M.D. Burghill, Hereford.
1874. ‡*Charles, John James, M.A., M.D.* 11 *Fisherwick-place, Belfast.*
1836. CHARLESWORTH, EDWARD, F.G.S. 277 Strand, London, W.C.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A., F.R.G.S. Junior Garrick Club, Adelphi-terrace, London, W.C.
1886. ‡Chate, Robert W. Southfield, Edgbaston, Birmingham.
1883. ‡Chater, Rev. John. Part-street, Southport.
1884. *Chatterton, George, M.A., M.Inst.C.E. 46 Queen Anne's-gate, London, S.W.
1886. §Chattock, A. P. 15 Lancaster-road, Belsize Park, London, N.W.
1867. *Chatwood, Samuel, F.R.G.S. Irwell House, Drinkwater Park, Prestwich.
1884. ‡CHAUVEAU, The Hon. Dr. Montreal, Canada.
1883. ‡Chawner, W., M.A. Emmanuel College, Cambridge.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, S.W.
1887. §Cheetham, F. W. Limefield House, Hyde.
1887. ‡Cheetham, John. Limefield House, Hyde.
1874. *Chermside, Lieut.-Colonel H. C., R.E., C.B. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, London, S.W.
1884. ‡Cherriman, Professor J. B. Ottawa, Canada.
1879. *Chesterman, W. Clarkehouse-road, Sheffield.
CHICHESTER, The Right Rev. RICHARD DURNFORD, D.D., Lord Bishop of. Chichester.
1865. *Child, Gilbert W., M.A., M.D., F.L.S. Cowley House, Oxford.
1883. §Chinery, Edward F. Monmouth House, Lymington.
1884. ‡Chipman, W. W. L. 6 Place d'Armes, Ontario, Canada.
1889. §Chirney, J. W. Morpeth.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. The Rectory, Beaconsfield R.S.O., Bucks.
1882. ‡Chorley, George. Midhurst, Sussex.
1887. ‡Chorlton, J. Clayton. New Holme, Withington, Manchester.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
1884. *Christie, William. 29 Queen's Park, Toronto, Canada.

Year of Election.

1875. *Christopher, George, F.C.S. 6 Barrow-road, Streatham Common, London, S.W.
1876. *Chrystal, George, M.A., F.R.S.E., Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1870. §Church, A. H., M.A., F.R.S., F.C.S., Professor of Chemistry to the Royal Academy of Arts, London. Shelsley, Ennerdale-road, Kew, Surrey.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.
1881. ‡Churchill, Lord Alfred Spencer. 16 Rutland-gate, London, S.W.
1857. ‡Churchill, F., M.D. Ardtrea Rectory, Stewartstown, Co. Tyrone.
1857. ‡Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square, Dublin.
1876. ‡Clark, David R., M.A. 31 Waterloo-street, Glasgow.
1890. §Clark, E. K. 81 Caledonian-road, Leeds.
1877. *Clark, F. J. Street, Somerset.
Clark, George T. 44 Berkeley-square, London, W.
1876. ‡Clark, George W. 31 Waterloo-street, Glasgow.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc., F.G.S. 20 Bootham, York.
1861. ‡Clark, Latimer, F.R.S., M.Inst.C.E. 11 Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1883. ‡Clarke, Rev. Canon, D.D. 59 Hoghton-street, Southport.
1887. §Clarke, C. Goddard. Folkestone Villa, Elm-grove, Peckham, S.E.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
1886. ‡Clarke, David. Langley-road, Small Heath, Birmingham.
1886. §Clarke, Rev. H. J. Great Barr Vicarage, Birmingham.
1872. *Clarke, Hyde. 32 St. George's-square, Pimlico, London, S.W.
1875. ‡Clarke, John Henry. 4 Worcester-terrace, Clifton, Bristol.
1861. *Clarke, John Hope. 62 Nelson-street, Chorlton-on-Medlock, Manchester.
1877. ‡Clarke, Professor John W. University of Chicago, Illinois, U.S.A.
1851. ‡Clarke, Joshua, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1883. ‡Clarke, W. P., J.P. 15 Hesketh-street, Southport.
1884. ‡Claxton, T. James. 461 St. Urbain-street, Montreal, Canada.
1861. ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1889. §Clayden, A. W. Warleigh, Palace-road, Tulse Hill Park, London, S.W.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1890. *Clayton, William Wikely. Outwood Villa, Spencer-place, Leeds.
1850. ‡Cleghorn, Hugh, M.D., F.L.S. Stravithie, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1861. §Cleland, John, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 College, Glasgow.
1873. ‡Cliff, John, F.G.S. Nesbit Hall, Fulneck, Leeds.
1886. ‡Clifford, Arthur. Beechcroft, Edgbaston, Birmingham.
1883. ‡*Clift, Frederic, LL.D. Norwood, Surrey.*
1888. ‡Clifton, The Right Rev. the Bishop of, D.D. Bishop's House, Clifton, Bristol.

Year of Election.

1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.

Clonbrock, Lord Robert. Clonbrock, Galway.

1878. §Close, Rev. Maxwell H., F.G.S. 40 Lower Baggot-street, Dublin.

1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.

1883. *CLOWES, FRANK, D.Sc., F.C.S., Professor of Chemistry in University College, Nottingham. University College, Nottingham.

1863. *Clutterbuck, Thomas. Warkworth, Acklington.

1881. *Clutton, William James. The Mount, York.

1885. ‡Clyne James. Rubislaw Den South, Aberdeen.

1868. ‡Coaks, J. B. Thorpe, Norwich.

Cobb, Edward. Falkland House, St. Ann's, Lewes.

1884. §Cobb, John. 29 Clarendon-road, Leeds.

1889. §Cochrane, Cecil A. Oakfield House, Gosforth, Newcastle-upon-Tyne.

1864. **Cochrane, James Henry. Elm Lodge, Prestbury, Cheltenham.*

1889. ‡Cochrane, William. Oakfield House, Gosforth, Newcastle-upon-Tyne.

1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.

1861. *Coe, Rev. Charles C., F.R.G.S. Fairfield, Heaton, Bolton.

1881. *COFFIN, WALTER HARRIS, F.C.S. 94 Cornwall-gardens, South Kensington, London, S.W.

1865. ‡Coghill, H. Newcastle-under-Lyme.

1884. *Cohen, B. L. 30 Hyde Park-gardens, London, W.

1887. §Cohen, Julius B. Hawkesmoor, Wilbraham-road, Fallowfield, Manchester.

1887. ‡Cohen, Sigismund. 111 Portland-street, Manchester.

1853. ‡Colchester, William, F.G.S. Burwell, Cambridge.

1868. ‡Colchester, W. P. Bassingbourn, Royston.

1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.

1878. ‡Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, London, W.

1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.

1857. ‡Colles, William, M.D. 21 Stephen's-green, Dublin.

1887. ‡Collie, Norman. University College, Gower-street, London, W.C.

1887. ‡Collier, Thomas. Ashfield, Alderley Edge, Manchester.

1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.

1854. ‡Collingwood, Cuthbert, M.A., M.B., F.L.S. 69 Great Russell-street, London, W.C.

1861. *Collingwood, J. Frederick, F.G.S. 96 Great Portland-street, London, W.

1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.

1876. ‡COLLINS, J. H., F.G.S. 4 Clark-terrace, Dulwich Rise, London, S.E.

1876. ‡Collins, Sir William. 3 Park-terrace East, Glasgow.

1884. §Collins, William J., M.D., B.Sc. Albert-terrace, Regent's Park, London, N.W.

1868. *COLMAN, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.

1882. ‡Colmer, Joseph G., C.M.G. Office of the High Commissioner for Canada, 9 Victoria-chambers, London, S.W.

1884. ‡Colomb, Sir J. C. R., M.P., F.R.G.S. Dromquinna, Kenmare, Kerry, Ireland; and Junior United Service Club, London, S.W.

1888. ‡Commans, R. D. Macaulay-buildings, Bath.

1884. ‡Common, A. A., F.R.S., F.R.A.S. 63 Eaton-rise, Ealing, Middlesex, W.

1884. §Conklin, Dr. William A. Central Park, New York, U.S.A.

1852. ‡Connal, Sir Michael. 16 Lynedoch-terrace, Glasgow.

Year of Election.

1890. §Connon, J W. Park-row, Leeds.
1871. *Connor, Charles C. Notting Hill House, Belfast.
1881. ‡CONROY, Sir JOHN, Bart. Balliol College, Oxford.
1876. ‡Cook, James. 162 North-street, Glasgow.
1882. ‡COOKE, Major-General A. C., R.E., C.B., F.R.G.S. Palace-chambers, Ryder-street, London, S.W.
1876. *COOKE, CONRAD W. 2 Victoria-mansions, Victoria-street, London, S.W.
1881. ‡Cooke, F. Bishopshill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
1868. ‡COOKE, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
1884. ‡Cooke, R. P. Brockville, Ontario, Canada.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
1881. ‡Cooke, Thomas. Bishopshill, York.
1859. *Cooke, His Honour Judge, M.A., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
1883. ‡Cooke-Taylor, R. Whateley. Frenchwood House, Preston.
1883. ‡Cooke-Taylor, Mrs. Frenchwood House, Preston.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1888. §Cooley, George Parkin. Cavendish Hill, Sherwood, Nottingham.
1883. ‡Coomer, John. Willaston, near Nantwich.
1884. ‡Coon, John S. 604 Main-street, Cambridge Pt., Massachusetts, U.S.A.
1883. ‡Cooper, George B. 67 Great Russell-street, London, W.C.
1850. ‡COOPER, Sir HENRY, M.D. 7 Charlotte-street, Hull.
1838. Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1884. ‡Cooper, Mrs. M. A. West Tower, Marple, Cheshire.
1868. ‡*Cooper, W. J. The Old Palace, Richmond, Surrey.*
1846. ‡*Cooper, William White, F.R.C.S.* 19 *Berkeley-square, London, W.*
1889. ‡Coote, Arthur. The Minories, Jesmond, Newcastle-upon-Tyne.
1884. ‡Cope, E. D. Philadelphia, U.S.A.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1871. ‡Copeland, Ralph, Ph.D., F.R.A.S., Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh.
1885. ‡Copland, W., M.A. Tortorston, Peterhead, N.B.
1881. ‡Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1863. ‡Coppin, John. North Shields.
1842. Corbett, Edward. Grange-avenue, Levenshulme, Manchester.
1887. *Corcoran, Bryan. 31 Mark-lane, London, E.C.
1881. §Cordeaux, John. Great Cotes, Ulceby, Lincolnshire.
1883. *Core, Thomas H. Fallowfield, Manchester.
1870. *CORFIELD, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiene and Public Health in University College. 19 Savile-row, London, W.
1889. ‡Cornish, Vaughan. Ivy Cottage, Newcastle, Staffordshire.
1884. *Cornwallis, F. S. W. Linton Park, Maidstone.
1885. ‡Corry, John. Rosenheim, Parkhill-road, Croydon.
1888. §Corser, Rev. Richard K. 12 Beaufort-buildings East, Bath.
1883. ‡Costelloe, B. F. C., M.A., B.Sc. 33 Chancery-lane, London, W.C.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. King-street, Manchester.
1874. *COTTERILL, J. H., M.A., F.R.S., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864. ‡COTTON, General FREDERICK C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, London, S.W.
1869. ‡COTTON, WILLIAM. Pennsylvania, Exeter.
1879. ‡Cottrill, Gilbert I. Shepton Mallett, Somerset.

Year of Election.

1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1874. ‡Courtauld, John M. Bocking Bridge, Braintree, Essex.
1889. ‡Courtney, F. S. 77 Redcliffe-square, South Kensington, London, S.W.
1890. §Cousins, John James. Allerton Park, Chapel Allerton, Leeds.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1876. ‡Cowan, J. B., M.D. 4 Eglinton-crescent, Edinburgh.
1872. *Cowan, Thomas William, F.G.S. Comptons Lea, Horsham.
1886. §Cowen, Mrs. G. R. 9 The Ropewalk, Nottingham.
Cowie, The Very Rev. Benjamin Morgan, M.A., D.D., Dean of Exeter. The Deanery, Exeter.
1871. ‡Cowper, C. E. 6 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.Inst.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Lyndhurst, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway. Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, London, S.W.
1867. *Cox, Thomas Hunter. Duncarse, Dundee.
1888. ‡Cox, Thomas W. B. The Chestnuts, Lansdown, Bath.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1883. §Crabtree, William, M.Inst.C.E. Manchester-road, Southport.
1890. §Cradock, George. Wakefield.
1884. §Craigie, Major P. G., F.S.S. 6 Lyndhurst-road, Hampstead, London, N.W.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1884. ‡Crathern, James. Sherbrooke-street, Montreal, Canada.
1887. §Craven, John. Smedley Lodge, Cheetham, Manchester.
1887. *Craven, Thomas, J.P. Woodheyes Park, Ashton-upon-Mersey, Cheshire.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Slateford, Edinburgh.
1871. *Crawford and Balcarres, The Right Hon. the Earl of, LL.D. F.R.S., F.R.A.S. The Observatory, Dun Echt, Aberdeen.
1890. §Crawshaw, Charles B. Bank-terrace, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, London, N.
1870. *Crawshay, Mrs. Robert. Cathedine, Bwlch, Breconshire.
1885. §Creak, Staff Commander E. W., R.N., F.R.S. Richmond Lodge, Blackheath, London, S.E.
1879. ‡Creswick, Nathaniel. Chantry Grange, near Sheffield.
1876. *Crewdson, Rev. George. St. George's Vicarage, Kendal.
1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
1880. *Crisp, Frank, B.A., LL.B., F.L.S. 5 Lansdowne-road, Notting Hill, London, W.
1890. *Croft, W. Winchester College, Hampshire.
1878. ‡*Croke, John O'Byrne, M.A. 12 Plevna-terrace, St. Mary's-road, Dublin.*
1859. ‡*Croll, A. A. 10 Coleman-street, London, E.C.*
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1885. ‡Crombie, Charles W. 41 Carden-place, Aberdeen.
1885. ‡Crombie, John. 129 Union-street, Aberdeen.
1885. ‡Crombie, John, jun. Daveston, Aberdeen.

Year of Election.

1885. ‡Crombie, J. W., M.A. Balgownie Lodge, Aberdeen.
1885. ‡Crombie, Theodore. 18 Albyn-place, Aberdeen.
1887. ‡Crompton, A. 1 St. James's-square, Manchester.
1886. ‡Crompton, Dickinson W. 40 Harborne-road, Edgbaston, Birmingham.
1887. §Crook, Henry T. 9 Albert-square, Manchester.
1870. ‡*Crookes, Joseph. Marlborough House, Brook Green, Hammersmith, London, W.*
1865. §Crookes, William, F.R.S., F.C.S. 7 Kensington Park-gardens, London, W.
1879. ‡Crookes, Mrs. 7 Kensington Park-gardens, London, W.
1870. ‡Crosfield, C. J. Holmfield, Aigburth, Liverpool.
1870. *Crosfield, William. Annesley, Aigburth, Liverpool.
1890. §Cross, E. Richard, LL.B. Harwood House, New Parks-crescent Scarborough.
1887. §Cross, John. Beancliffe, Alderley Edge, Cheshire.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1883. ‡Cross, Rev. Prebendary, LL.B. Part-street, Southport.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1886. ‡Crosskey, Cecil. 117 Gough-road, Birmingham.
1867. §Crosskey, Rev. H. W., LL.D., F.G.S. 117 Gough-road, Birmingham.
1853. ‡Crosskill, William. Beverley, Yorkshire.
1870. *Crossley, Edward, M.P., F.R.A.S. Bemerside, Halifax.
1871. ‡Crossley, Herbert. Ferney Green, Bowness, Ambleside.
1866. *Crossley, Louis J., F.R.M.S. Moorside Observatory, near Halifax.
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1883. ‡Crowder, Robert. Stanwix, Carlisle.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1890. *Crowley, Ralph Henry. Bramley Oaks, Croydon.
1883. ‡Crowther, Elon. Cambridge-road, Huddersfield.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.
1885. ‡Cruickshank, Alexander, LL.D. 20 Rose-street, Aberdeen.
1888. ‡Crummack, William J. London and Brazilian Bank, Rio de Janeiro, Brazil.
1873. ‡Crust, Walter. Hall-street, Spalding.
1883. *Cryer, Major J. H. The Grove, Manchester-road, Southport.
Culley, Robert. Bank of Ireland, Dublin.
1883. *Culverwell, Edward P. 40 Trinity College, Dublin.
1878. ‡Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1882. *Cunningham, Lieut.-Colonel Allan, R.E., A.I.C.E. C.R.E.'s Office, Camp, Shorncliffe, Kent.
1887. ‡Cunningham, David, M.Inst.C.E., F.R.S.E., F.S.S. Harbour-chambers, Dundee; and Viewbank, Newport, Fife, Scotland.
1877. *Cunningham, D. J., M.D., Professor of Anatomy in Trinity College, Dublin.
1852. ‡Cunningham, John. Macedon, near Belfast.
1885. ‡Cunningham, J. T., B.A., F.R.S.E. Scottish Marine Station, Granton, Edinburgh.
1869. ‡Cunningham, Robert O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1883. *Cunningham, Rev. William, D.D., D.Sc. Trinity College, Cambridge.
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.

Year of Election.

1885. ‡Curphey, William S. 268 Renfrew-street, Glasgow.
1884. ‡Currier, John McNab. Newport, Vermont, U.S.A.
1867. **Cursetjee, Manockjee, F.R.G.S., Judge of Bombay. Villa-Byculla, Bombay.*
1857. ‡CURTIS, ARTHUR HILL, LL.D. 1 Hume-street, Dublin.
1878. ‡Curtis, William. Caramore, Sutton, Co. Dublin.
1884. ‡Cushing, Frank Hamilton. Washington, U.S.A.
1883. ‡Cushing, Mrs. M. Croydon, Surrey.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, London, S.W.

1889. §Dagger, John H., F.I.C., F.C.S. Endon, Staffordshire.
1854. ‡Daglish, Robert, M.Inst.C.E. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1889. *Dale, Miss Elizabeth. Girton College, Cambridge.
1887. ‡Dale, Henry F., F.R.M.S., F Z.S. Royal London Yacht Club, 2 Savile-row, London, W.
1863. ‡Dale, J. B. South Shields.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W. Dundee.
1870. ‡DALLINGER, Rev. W. H., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, London, S.E.
Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.
1862. ‡DANBY, T. W., M.A., F.G.S. 1 Westbourne-terrace-road, London, W.
1876. ‡Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A., F.G.S. 26 George-street, Manchester.
1883. ‡*Darbishire, S. D., M.D. 60 High-street, Oxford.*
1876. ‡Darling, G. Erskine. 247 West George-street, Glasgow.
1884. ‡Darling, Thomas. 99 Drummond-street, Montreal, Canada.
1882. ‡DARWIN, FRANCIS, M.A., M.B., F.R.S., F.L.S. Wychfield, Huntingdon-road, Cambridge.
1881. *DARWIN, GEORGE HOWARD, M.A., LL.D., F.R.S., F.R.A.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.
1878. *Darwin, Horace. The Orchard, Huntingdon-road, Cambridge.
1882. ‡Darwin, W. E., F.G.S. Bassett, Southampton.
1888. ‡Daubeny, William M. Stratton House, Park-lane, Bath.
1872. ‡Davenport, John T. 64 Marine Parade, Brighton.
1880. *DAVEY, HENRY, M.Inst.C.E. 3 Prince's-street, Westminster, S.W.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, London, E.C.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1885. ‡Davidson, Charles B. Roundhay, Fonthill-road, Aberdeen.
1890. §Davies, Arthur. East Brow Cottage, near Whitby.
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1842. Davies-Colley, Dr. Thomas. Newton, near Chester.
1887. ‡Davies-Colley, T. C. Hopedene, Kersal, Manchester.
1873. *Davis, Alfred. 2 St. Ermin's Mansions, London, S.W.
1870. *Davis, A. S. Vittoria House, Cheltenham.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.

Year of Election.

1887. §Davis, David. 55 Berkley-street, Liverpool.
1842. Davis, Rev. David, B.A. Almswood, Evesham.
1881. ‡*Davis, George E. The Willows, Fallowfield, Manchester.*
1882. §Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1873. *DAVIS, JAMES W., F.G.S., F.S.A. Chevinedge, near Halifax.
1883. ‡*Davis, Joseph, J.P. Park-road, Southport.*
1883. ‡Davis, Robert Frederick, M.A. Earlsfield, Wandsworth Common, London, S.W.
1885. *Davis, Rudolf. Almswood, Evesham.
1886. ‡Davis, W. H. Hazeldean, Pershore-road, Birmingham.
1886. ‡Davison, Charles, M.A. 38 Charlotte-road, Birmingham.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡DAVY, EDMUND W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. R. M. Bedford-circus, Exeter.
1860. *Dawes, John T., F.G.S. Cefn Mawr Hall, Mold, North Wales.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.G.S., F.S.A., Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
1886. ‡Dawson, Bernard. The Laurels, Malvern Link.
1885. *Dawson, Major H. P., R.A. Sheerness.
1884. ‡Dawson, Samuel. 258 University-street, Montreal, Canada.
1855. §DAWSON, Sir WILLIAM, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal of McGill University. McGill University, Montreal, Canada.
1859. *Dawson, Captain William G. Plumstead Common, Kent.
1871. ‡*Day, St. John Vincent, M.Inst.C.E., F.R.S.E.* 166 *Buchanan-street, Glasgow.*
1870. *DEACON, G. F., M.Inst.C.E. Municipal Offices, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1887. ‡Deakin, H. T. Egremont House, Belmont, near Bolton.
1861. ‡Dean, Henry. Colne, Lancashire.
1870. *Deane, Rev. George, B.A., D.Sc., F.G.S. 38 Wellington-road, Birmingham.
1884. *Debenham, Frank, F.S.S. 26 Upper Hamilton-terrace, London, N.W.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S., Lecturer on Chemistry at Guy's Hospital, London, S.E.
1884. §Deck, Arthur, F.C.S. 9 King's-parade, Cambridge.
1887. §Dehn, R. Olga Villa, Victoria Park, Manchester.
1878. ‡Delany, Rev. William. St. Stanislaus College, Tullamore.
1879. ‡De la Sala, Colonel. Sevilla House, Navarino-road, London, N.W.
1884. *De Laune, C. De L. F. Sharsted Court, Sittingbourne.
1887. ‡*De Meschin, Miss Hannah Constance. Sandycove Castle, Kingstown, Ireland.*
1870. §*De Meschin, Thomas, B.A., LL.D. Sandycove Castle, Kingstown, Ireland.*
1889. ‡Dendy, Frederick Walter. 3 Mardale-parade, Gateshead.
1873. ‡Denham, Thomas, J.P. Huddersfield.
1884. ‡Denman, Thomas W. Lamb's-buildings, Temple, London, E.C.
1889. §DENNY, ALFRED, F.L.S., Professor of Biology in the Firth College, Sheffield.
Dent, William Yerbury. Royal Arsenal, Woolwich.
1870. *Denton, J. Bailey. Orchard Court, Stevenage.
1874. §DE RANCE, CHARLES E., F.G.S. 28 Jermyn-street, London, S.W.

Year of Election.

1856. *DERBY, The Right Hon. the Earl of, K.G., M.A., LL.D., F.R.S., F.R.G.S. St. James's-square, London, S.W.; and Knowsley, near Liverpool.
1874. *Derham, Walter, M.A., LL.M., F.G.S. 76 Lancaster-gate, London, W.
1878. ‡De Rinzy, James Harward. Khelat Survey, Sukkur, India.
1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
DE TABLEY, Lord GEORGE, F.Z.S. Tabley House, Knutsford, Cheshire.
*DEVONSHIRE, His Grace the Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.
1868. ‡DEWAR, JAMES, M.A., F.R.S. L. & E., F.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. 1 Scroope-terrace, Cambridge.
1881. ‡Dewar, Mrs. 1 Scroope-terrace, Cambridge.
1883. ‡Dewar, James, M.D., F.R.C.S.E. Drylaw House, Davidson's Mains, Midlothian, N.B.
1884. *Dewar, William, M.A. Rugby School, Rugby.
1872. ‡Dewick, Rev. E. S., M.A., F.G.S. 26 Oxford-square, London, W.
1887. ‡DE WINTON, Colonel Sir F., K.C.M.G., C.B., D.C.L., Sec. R.G.S. United Service Club, Pall Mall, London, S.W.
1884. ‡De Wolf, O. C., M.D. Chicago, U.S.A.
1873. *DEW-SMITH, A. G., M.A. Trinity College, Cambridge.
1889. ‡Dickinson, A. H. Portland House, Newcastle-upon-Tyne.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-upon-Tyne.
1887. ‡Dickinson, Joseph, F.G.S. South Bank, Pendleton.
1884. ‡Dickson, Charles R., M.D. Wolfe Island, Ontario, Canada.
1881. ‡Dickson, Edmund. West Cliff, Preston.
1887. ‡Dickson, H. N. 38 York-place, Edinburgh.
1885. ‡Dickson, Patrick. Laurencekirk, Aberdeen.
1883. ‡Dickson, T. A. West Cliff, Preston.
1862. *DILKE, The Right Hon. Sir CHARLES WENTWORTH, Bart., F.R.G.S. 76 Sloane-street, London, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1848. ‡DILLWYN, LEWIS LLEWELYN, M.P., F.L.S., F.G.S. Parkwerne, near Swansea.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1889. ‡Dinning, William. 41 Eldon-street, Newcastle-upon-Tyne.
1876. ‡Ditchfield, Arthur. 12 Taviton-street, Gordon-square, London, W.C.
1868. ‡Dittmar, William, LL.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in the Glasgow and West of Scotland Technical College, 11 Hillhead-street, Glasgow.
1884. ‡Dix, John William H. Bristol.
1874. *Dixon, A. E. Dunowen, Cliftonville, Belfast.
1883. ‡Dixon, Miss E. 2 Cliff-terrace, Kendal.
1888. §Dixon, E. T. Messrs. Lloyds, Barnetts, & Bosanquets' Bank, 54 St. James's-street, London, S.W.
1886. ‡Dixon, George. 42 Augustus-road, Edgbaston, Birmingham.
1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S., Professor of Chemistry in the Owens College, Manchester. Birch Hall, Rusholme, Manchester.
1885. ‡Dixon, John Henry. Inveran, Poolewe, Ross-shire, N.B.
1887. ‡Dixon, Thomas. Buttershaw, near Bradford, Yorkshire.
1885. ‡Doak, Rev. A. 15 Queen's-road, Aberdeen.

Year of
Election.

1890. §Dobbie, James J. University College, Bangor, North Wales.
1885. §Dobbin, Leonard. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne Park, London, W.
1878. *DOBSON, G. E., M.A., M.B., F.R.S., F.L.S. Adrigole, Spring Grove, Isleworth.
1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.
1875. *Docwra, George, jun. 32 Union-street, Coventry.
1870. *Dodd, John. Nunthorpe-avenue, York.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1889. §Dodson, George, B.A. Downing College, Cambridge.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1885. ‡Donaldson, James, M.A., LL.D., F.R.S.E., Senior Principal of the University of St. Andrews, N.B.
1882. ‡Donaldson, John. Tower House, Chiswick, Middlesex.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *Donkin, Bryan, jun. May's Hill, Shortlands, Kent.
1889. ‡Donkin, R. S., M.P. Campville, North Shields.
1861. ‡Donnelly, Colonel, R.E., C.B. South Kensington Museum, London, S.W.
1887. ‡Donner, Edward, B.A. 4 Anson-road, Victoria Park, Manchester.
1887. ‡Dorning, Elias, M.Inst.C.E., F.G.S. 41 John Dalton-street, Manchester.
1881. ‡Dorrington, John Edward. Lypiatt Park, Stroud.
1889. ‡Dorsey, E. B. International Club, Trafalgar-square, London, S.W.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871. ‡*Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.*
1863. *Doughty, Charles Montagu. Care of H. M. Doughty, Esq., 5 Stone-court, Lincoln's Inn, London, W.C.
1876. *Douglas, Rev. G. C. M. 18 Royal-crescent West, Glasgow.
1877. *DOUGLASS, Sir JAMES N., F.R.S., M.Inst.C.E. Trinity House, London, E.C.
1884. ‡Douglass, William Alexander. Freehold Loan and Savings Company, Church-street, Toronto, Canada.
1890. ‡Dovaston, John. West Felton, Oswestry.
1883. ‡Dove, Arthur. Crown Cottage, York.
1884. ‡Dove, Miss Frances. St. Leonard's, St. Andrews, N.B.
1884. ‡Dove, P. Edward, F.R.A.S., Sec.R.Hist.Soc. 23 Old-buildings, Lincoln's Inn, London, W.C.
1884. ‡Dowe, John Melnotte. 69 Seventh-avenue, New York, U.S.A.
1876. ‡Dowie, Mrs. Muir. Golland, by Kinross, N.B.
1884. *Dowling, D. J. Bromley, Kent.
1878. ‡*Dowling Thomas. Claireville House, Terenure, Dublin.*
1857. ‡DOWNING, S., LL.D. 4 The Hill, Monkstown, Co. Dublin.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, Joseph Emerson, M.Inst.C.E. 3 Great Queen-street, London, S.W.
1887. §Doxey, R. A. Slade House, Levenshulme, Manchester.
1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1868. ‡DRESSER, HENRY E., F.Z.S. 110 Cannon-street, London, E.C.
1873. §DREW, FREDERIC, F.G.S., F.R.G.S. Eton College, Windsor.
1890 §Drew, John. 12 Haringay Park, Crouch End, Middlesex, N.
1887. ‡Dreyfus, Dr Daisy Mount, Victoria Park, Manchester.
1889. ‡Drummond, Dr. 6 Saville-place, Newcastle-upon-Tyne.
1870. ‡Drysdale, J. J., M.D. 36A Rodney-street, Liverpool.
1889. ‡Du Chaillu, Paul B. Care of John Murray, Esq., 50A Albemarle-street, London, W.

Year of Election.

1856. *DUCIE, The Right. Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Christchurch Vicarage, Chester.
1867. *DUFF, The Right Hon. Sir MOUNTSTUART ELPHINSTONE GRANT-, G.C.S.I., F.R.S., Pres.R.G.S. York House, Twickenham.
1852. ‡Dufferin and Ava, The Most Hon. the Marquis of, K.P., G.C.B., G.C.M.G., G.C.S.I., D.C.L., LL.D., F.R.S., F.R.G.S. Clandeboye, near Belfast, Ireland.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange. Waterford.
1890. §Dufton, S. F. Trinity College, Cambridge.
1884. §Dugdale, James H. 9 Hyde Park-gardens, London, W.
1883. §Duke, Frederic. Conservative Club, Hastings.
1859. *Duncan, Alexander. 7 Prince's-gate, London, S.W.
1866. *Duncan, James. 9 Mincing-lane, London, E.C.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1867. ‡DUNCAN, PETER MARTIN, M.B., F.R.S., F.G.S., Professor of Geology in King's College, London. 6 Grosvenor-road, Gunnersbury, London, W.
1880. ‡Duncan, William S. 143 Queen's-road, Bayswater, London, W.
1881. ‡Duncombe, The Hon. Cecil. Nawton Grange, York.
1881. ‡Dunhill, Charles H. Gray's-court, York.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1882. §Dunn, J. T., M.Sc., F.C.S. High School for Boys, Gateshead-on-Tyne.
1883. ‡Dunn, Mrs. Denton Grange, Gateshead-on-Tyne.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. ‡Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
1884. §Dunnington, F. P. University of Virginia, Albemarle Co., Virginia, U.S.A.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1890. §Dunsford, Follett. Rougemont Villa, Headingley, Leeds.
1885. *DUNSTAN, WYNDHAM R., M.A., F.C.S., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 17 Bloomsbury-square, London, W.C.
1866. ‡Duprey, Perry. Woodberry Down, Stoke Newington, London, N.
1869. ‡D'Urban, W. S. M., F.L.S. 4 Queen-terrace, Mount Radford, Exeter.
1860. ‡DURHAM, ARTHUR EDWARD, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
1887. ‡Durham, William. Seaforth House, Portobello, Scotland.
1887. ‡Dyason, John Sanford, F.R.G.S., F.R.Met.Soc. Boscobel-gardens, London, N.W.
1884. ‡Dyck, Professor Walter. The University, Munich.
1885. *Dyer, Henry, M.A. 8 Highburgh-terrace, Dowanhill, Glasgow.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Woburn.

1868. ‡Eade, Peter, M.D. Upper St. Giles's-street, Norwich.
1861. ‡*Eadson, Richard.* 13 *Hyde-road, Manchester.*
1883. ‡Eagar, Rev. Thomas. The Rectory, Ashton-under-Lyne.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
1888. ‡Earson, H. W. P. 11 Alexandra-road, Clifton, Bristol.
1874. ‡Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.

Year of Election.

1871. *EASTON, EDWARD, M.Inst.C.E., F.G.S. 11 Delahay-street, Westminster, S.W.
1863. ‡Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John. Durie House, Abercromby-street, Helensburgh, N.B.
1883. ‡Eastwood, Miss. Littleover Grange, Derby.
1887. §Eccles, Mrs. S. White Coppice, Chorley, Lancashire.
1884. ‡Eckersley, W. T. Standish Hall, Wigan, Lancashire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1858. *Eddison, Francis. Syward Lodge, Dorchester.
1870. *Eddison, John Edwin, M.D., M.R.C.S. 29 Park-square, Leeds.
*Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1887. §Ede, Francis J. Silchar, Cachar, India.
Eden, Thomas. Talbot-road, Oxton.
1884. *Edgell, R. Arnold, M.A., F.C.S. 58 Abingdon-villas, Kensington, London, W.
1887. §EDGEWORTH, F. Y., M.A., D.C.L., F.S.S., Professor of Political Economy in the University of Oxford. Athenæum Club, Pall Mall, London, S.W.
1870. *Edmonds, F. B. 6 Furnival's Inn, London, E.C.
1883. ‡Edmonds, William. Wiscombe Park, Honiton, Devon.
1888. *Edmunds, Henry. Rhodehurst, Streatham, London, S.W.
1884. *Edmunds, James, M.D. 8 Grafton-street, Piccadilly, London, W.
1883. §Edmunds, Lewis, D.Sc., LL.B. 60 Park-street, Park-lane, London, W.
1867. *Edward, Allan. Farington Hall, Dundee.
1867. ‡*Edward, Charles. Chambers,* 8 *Bank-street, Dundee.*
1855. *EDWARDS, Professor J. BAKER, Ph.D., D.C.L. Montreal, Canada.
1884. ‡Edwards, W. F. Niles, Michigan, U.S.A.
1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1890. §Elford, Percy. Christ Church, Oxford.
1885. *Elgar, Francis, LL.D., F.R.S.E., Director of H.M. Dockyards. The Admiralty, London, S.W.
1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. Manor Cottage, Kempston, Bedford.
1863. ‡Ellenberger, J. L. Worksop.
1885. ‡Ellingham, Frank. Thorpe St. Andrew, Norwich.
1883. ‡Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.
1864. ‡Elliott, E. B. Washington, U.S.A.
1883. *ELLIOTT, EDWIN BAILEY, M.A. Queen's College, Oxford.
Elliott, John Fogg. Elvet Hill, Durham.
1879. ‡Elliott, Joseph W. Post Office, Bury, Lancashire.
1886. §Elliott, Thomas Henry, F.S.S. Local Government Board, Whitehall, London, S.W.
1877. ‡Ellis, Arthur Devonshire. School of Mines, Jermyn-street, London, S.W.; and Thurnscoe Hall, Rotherham, Yorkshire.
1875. *Ellis, H. D. 6 Westbourne-terrace, Hyde Park, London, W.
1883. ‡Ellis, John. 17 Church-street, Southport.
1880. *ELLIS, JOHN HENRY. New Close, Cambridge-road, Southport.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1864. ‡*Ellis, J. Walter. High House, Thornwaite, Ripley, Yorkshire.*
1884. ‡Ellis, W. Hodgson. Toronto, Canada.
1869. ‡ELLIS, WILLIAM HORTON. Hartwell House, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.

Year of Election.

1887. ‡Elmy, Ben. Eaton Hall, Congleton, Manchester.
1862. ‡Elphinstone, H. W., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, London, W.C.
1883. ‡Elwes, George Robert. Bossington, Bournemouth.
1887. §Elworthy, Frederick T. Foxdown, Wellington, Somerset.
1870. *Ely, The Right Rev. Lord Alwyne Compton, D.D., Lord Bishop of. The Palace, Ely, Cambridgeshire.
1863. ‡Embleton, Dennis, M.D. 19 Claremont-place, Newcastle-upon-Tyne.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1886. ‡*Emmons, Hamilton. Mount Vernon Lodge, Leamington.*
1858. ‡Empson, Christopher. Bramhope Hall, Leeds.
1890. §Emsley, Alderman W. Richmond House, Richmond-road, Headingley, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1884. ‡England, Luther M. Knowlton, Quebec, Canada.
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate Hull.
1869. ‡English, J. T. Wayfield House, Stratford-on-Avon.
1883. ‡Entwistle, James P. Beachfield, 2 Westclyffe-road, Southport.
1869. *Enys, John Davis. Care of F. G. Enys, Esq., Enys, Penryn, Cornwall.
1844. ‡Erichsen, John Eric, LL.D., F.R.S., F.R.C.S., President of, and Emeritus Professor of Surgery in, University College, London. 6 Cavendish-place, London, W.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.
1885. ‡Esselmont, Peter, M.P. 34 Albyn-place, Aberdeen.
1862. *Esson, William, M.A., F.R.S., F.C.S., F.R.A.S. Merton College, and 13 Bradmore-road, Oxford.
1878. ‡Estcourt, Charles, F.C.S. 8 St. James's-square, John Dalton-street, Manchester.
1887. *Estcourt, Charles. Vyrnieu House, Talbot-road, Old Trafford, Manchester.
1887. *Estcourt, P. A. Vyrnieu House, Talbot-road, Old Trafford, Manchester.
Estcourt, Rev. W. J. B. Long Newton, Tetbury.
1869. ‡Etheridge, Robert, F.R.S. L. & E., F.G.S., Assistant Keeper (Geological and Palæontological Department) Natural History Museum (British Museum). 14 Carlyle-square, London, S.W.
1888. ‡Etheridge, Mrs. 14 Carlyle-square, London, S.W.
1883. §Eunson, Henry J. Morvi, Kathiawar, Bombay Presidency.
1881. ‡*Evans, Alfred. Exeter College, Oxford.*
1889. *Evans, A. H. 9 Harvey-road, Cambridge.
1887. *Evans, Mrs. Alfred W. A. Hillside, New Mills, near Stockport, Derbyshire.
1870. *Evans, Arthur John, F.S.A. 33 Holywell, Oxford.
1865. *Evans, Rev. Charles, M.A. The Rectory, Solihull, Birmingham.
1889. §Evans, Henry Jones. Greenhill, Whitchurch, Cardiff.
1884. ‡Evans, Horace L. Moreton House, Tyndall's Park, Bristol.
1861. *Evans, John, D.C.L., LL.D., D.Sc., Treas.R.S., F.S.A., F.L.S., F.G.S. Nash Mills, Hemel Hempstead.
1883. *Evans, J. C. Albany-buildings, Lord-street, Southport.
1883. *Evans, Mrs. J. C. Albany-buildings, Lord-street, Southport.
1881. ‡Evans, Lewis. Llanfyrnach R.S.O., Pembrokeshire.
1876. ‡*Evans, Mortimer, M.Inst.C.E. 97 West Regent-street, Glasgow.*
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.

Year of Election.

1865. ‡*Evans, Sebastian, M.A., LL.D. Heathfield, Alleyne Park, Lower Norwood, Surrey, S.E.*
1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1865. *Evans, William. The Spring, Kenilworth.
1886. ‡Eve, A. S. Marlborough College, Wilts.
1871. ‡Eve, H. Weston, M.A. University College, London, W.C.
1868. *Everett, J. D., M.A., D.C.L., F.R.S. L. & E., Professor of Natural Philosophy in Queen's College, Belfast. 5 Princess-gardens, Belfast.
1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1886. ‡Everitt, William E. Finstall Park, Bromsgrove.
1883. ‡Eves, Miss Florence. Uxbridge.
1881. ‡Ewart, J. Cossar, M.D., Professor of Natural History in the University of Edinburgh.
1874. ‡Ewart, Sir W. Quartus, Bart. Glenmachan, Belfast.
1859. *Ewing, Sir Archibald Orr, Bart., M.P. Ballikinrain Castle, Killearn, Stirlingshire.
1876. *Ewing, James Alfred, M.A., B.Sc., F.R.S. L. & E., Professor of Mechanism and Applied Mathematics in the University of Cambridge.
1883. ‡Ewing, James L. 52 North Bridge, Edinburgh.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1884. *Eyerman, John. Easton, Pennsylvania, U.S.A.
1882. ‡Eyre, G. E. Briscoe. Warrens, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.

1890. §Faber, Edmund Beckett. Straylea, Harrogate.
1884. ‡*Fairbairn, Dr. A. M. Airedale College, Bradford, Yorkshire.*
1865. *Fairley, Thomas, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1870. ‡*Fairlie, Robert. Woodlands, Clapham Common, London, S.W.*
1886. ‡Fairley, William. Beau Desert, Rugeley, Staffordshire.
1864. ‡Falkner, F. H. Lyncombe, Bath.
1886. ‡*Fallon, T. P., Consul General. Australia.*
1883. ‡Fallon, Rev. W. S. 1 St. Alban's-terrace, Cheltenham.
1877. §Faraday, F. J., F.L.S., F.S.S. College-chambers, 17 Brazenose-street, Manchester.
1887. ‡Farmer, Sir James. Hope House, Eccles Old-road, Manchester.
1886. §Farncombe, Joseph, J.P. Lewes.
1879. *Farnworth, Ernest. Clarence Villa, Penn Fields, Wolverhampton.
1883. ‡Farnworth, Walter. 86 Preston New-road, Blackburn.
1883. ‡Farnworth, William. 86 Preston New-road, Blackburn.
1885. ‡Farquhar, Admiral. Carlogie, Aberdeen.
1859. ‡Farquharson, Robert F. O. Haughton, Aberdeen.
1885. ‡Farquharson, Mrs. R. F. O. Haughton, Aberdeen.
1866. *Farrar, Ven. Frederic William, M.A., D.D., F.R.S., Archdeacon of Westminster. 17 Dean's-yard Westminster, S.W.
1883. ‡Farrell, John Arthur. Moynalty, Kells, North Ireland.
1857. ‡Farrelly Rev. Thomas. Royal College, Maynooth.
1869. *Faulding, Joseph. Ebor Villa, Godwin-road, Clive-vale, Hastings.
1883. §Faulding, Mrs. Ebor Villa, Godwin-road, Cive-vale, Hastings.
1887. §Faulkner, John. 13 Great Ducie-street, Strangeways, Manchester.
1890. *Fawcett, F. B. Torfels, Weston-super-Mare.
1886. §Felkin, Robert W., M.D., F.R.G.S. 20 Alva-street, Edinburgh.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1864. *Fellows, Frank P., K.S.J.J., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. 9 College-square; and Keswick, near Belfast.

Year of Election.

1883. ‡Fenwick, E. H. 29 Harley-street, London, W.
1890. §Fenwick, T. Chapel Allerton, Leeds.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1883. ‡Ferguson, Mrs. A. A. 11 Grosvenor-terrace, Glasgow.
1859. ‡*Ferguson, John. Cove, Nigg, Inverness.*
1871. *FERGUSON, JOHN, M.A., LL.D., F.R.S.E., F.S.A., F.C.S., Professor of Chemistry in the University of Glasgow.
1867. ‡Ferguson, Robert M., Ph.D., F.R.S.E. 8 Queen-street, Edinburgh.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1883. ‡Fernald, H. P. Alma House, Cheltenham.
1883. *Fernie John. Box No. 2, Hutchinson, Kansas, U.S.A.
1862. ‡FERRERS, Rev. NORMAN MACLEOD, D.D., F.R.S. Caius College Lodge, Cambridge.
1873. ‡Ferrier, David, M.A., M.D., LL.D., F.R.S., Professor of Neuro-Pathology in King's College. 34 Cavendish-square, London, W.
1882. §Fewings, James, B.A., B.Sc. The Grammar School. Southampton.
1887. §Fiddes, Thomas, M.D. Penwood, Urmston, near Manchester.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1886. ‡Field, H. C. 4 Carpenter-road, Edgbaston, Birmingham.
1869. *FIELD, ROGERS, B.A., M.Inst.C.E. 4 Westminster-chambers, Westminster, S.W.
1887. ‡Fielden, John C. 145 Upper Brook-street, Manchester.
1882. ‡Filliter, Freeland. St. Martin's House, Wareham, Dorset.
1883. *Finch, Gerard B., M.A. 1 St. Peter's-terrace, Cambridge.
Finch, John. Bridge Work, Chepstow.
1885. ‡FINDLATER, JOHN. 60 Union-street, Aberdeen.
1878. *Findlater, William. 22 Fitzwilliam-square, Dublin.
1885. ‡Findlay, George, M.A. 50 Victoria-street, Aberdeen.
1884. ‡Finlay, Samuel. Montreal, Canada.
1887. ‡Finnemore, Rev. J., F.G.S. Aston-road, Birmingham.
1881. ‡Firth, Colonel Sir Charles. Heckmondwike.
Firth, Thomas. Northwich.
1863. *Firth, William. Burley Wood, near Leeds.
1858. ‡*Fishbourne, Admiral E. G., R.N. 26 Hogarth-road, Earl's Court-road, London, S.W.*
1884. *Fisher, L. C. Galveston, Texas, U.S.A.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlton Rectory, near Cambridge.
1873. ‡Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1879. ‡Fisher, William. Norton Grange, near Sheffield.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1887. *Fison, Alfred H., D.Sc. University College, London, W.C.
1885. ‡Fison, E. Herbert. Stoke House, Ipswich.
1871. *FISON, FREDERICK W., M.A., F.C.S. Greenholme, Burley-in-Wharfedale, near Leeds.
1871. ‡FITCH, J. G., M.A., LL.D. 5 Lancaster-terrace, Regent's Park, London, N.W.
1883. ‡Fitch, Rev. J. J. Ivyholme, Southport.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §FITZGERALD, GEORGE FRANCIS, M.A., F.R.S., Professor of Natural and Experimental Philosophy, Trinity College, Dublin.
1885. *Fitzgerald, Professor Maurice, B.A. 37 Botanic-avenue, Belfast.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Baggot-street, Dublin.
1888. *Fitzpatrick, Thoma C. Christ's College, Cambridge.

Year of Election.

1865. ‡Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.
1881. †Fleming, Rev. Canon James, B.D. The Residence, York.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, near Glasgow.
1876. ‡Fleming, Sandford. Ottawa, Canada.
1867. §FLETCHER, ALFRED E., F.C.S. 57 Gordon-square, London, W.C.
1870. ‡Fletcher, B. Edgington. Norwich.
1890. §Fletcher, B. Morley. 57 Gordon-square, London, W.C.
1886. †Fletcher, Frank M. 57 Gordon-square, London, W.C.
1869. ‡FLETCHER, LAVINGTON E., M.Inst.C.E. Alderley Edge, Cheshire.
1888. *FLETCHER, LAZARUS, M.A., F.R.S., F.G.S., F.C.S., Keeper of Minerals, British Museum (Natural History), Cromwell-road, London, S.W.
1862. §FLOWER, WILLIAM HENRY, C.B., LL.D., D.C.L., F.R.S., F.L.S., F.G.S., F.R.C.S., Director of the Natural History Departments, British Museum, South Kensington, London. 26 Stanhope-gardens, London, S.W.
1889. §Flower, Mrs. 26 Stanhope-gardens, London, S.W.
1877. *Floyer, Ernest A., F.R.G.S., F.L.S. Helwan, Egypt.
1890. §Flux, A. W., B.A. St. John's College, Cambridge.
1887. ‡Foale, William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1883. ‡Foale, Mrs. William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1881. ‡Foljambe, Cecil G. S., M.P. 2 Carlton House-terrace, Pall Mall, London, S.W.
1879. ‡Foote, Charles Newth, M.D. 3 Albion-place, Sunderland.
1880. ‡Foote, R. Bruce. Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.
1873. *FORBES, GEORGE, M.A., F.R.S. L. & E., M.Inst.C.E. 34 Great George-street, London, S.W.
1883. ‡Forbes, Henry O., F.Z.S., Director of the Canterbury Museum, Christchurch, New Zealand.
1885. ‡Forbes, The Right Hon. Lord. Castle Forbes, Aberdeenshire.
1890. §FORD, J. RAWLINSON. Quarry Dene, Weetwood-lane, Leeds.
1875. *FORDHAM, H. GEORGE, F.G.S. L'Aurore, Lausanne, Switzerland.
1883. §Formby, R. Formby, near Liverpool.
1887. ‡FORREST, JOHN, C.M.G., F.R.G.S. Perth, Western Australia.
1867. ‡Forster, Anthony. Finlay House, St. Leonards-on-Sea.
1883. ‡Forsyth, A. R., M.A., F.R.S. Trinity College, Cambridge.
1884. ‡Fort, George H. Lakefield, Ontario, Canada.
1877. ‡FORTESCUE, The Right Hon. the Earl. Castle Hill, North Devon.
1882. §Forward, Henry. 2 St. Agnes-terrace, Victoria Park-road, London, E.
1870. ‡Forwood, Sir William B. Hopeton House, Seaforth, Liverpool.
1875. ‡Foster, A. Le Neve. 51 Cadogan-square, London, S.W.
1865. ‡Foster, Balthazar, M.D., Professor of Medicine in Queen's College, Birmingham. 16 Temple-row, Birmingham.
1865. *FOSTER, CLEMENT LE NEVE, B.A., D.Sc., F.G.S., Professor of Mining in the Royal College of Science, London, S.W.
1883. ‡Foster, Mrs. C. Le Neve. Llandudno.
1857. *FOSTER, GEORGE CAREY, B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 18 Daleham-gardens, Hampstead, London, N.W.
1877. §Foster, Joseph B. 6 James-street, Plymouth.
1859. *FOSTER, MICHAEL, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S., Professor of Physiology in the University of Cambridge. Trinity College, and Great Shelford, near Cambridge.
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.

Year of Election.

1888. §Fowler, Gilbert J. Dalton Hall, Manchester.
1876. *Fowler, John. 4 Kelvin Bank-terrace, Sandyford, Glasgow.
1882. ‡FOWLER, Sir JOHN, Bart., K.C.M.G., M.Inst.C.E., F.G.S. 2 Queen Square-place, Westminster, S.W.
1870. *Fowler, Sir Robert Nicholas, Bart., M.A., M.P., F.R.G.S. 137 Harley-street, London, W.
1884. ‡Fox, Miss A. M. Penjerrick, Falmouth.
1883. *Fox, Charles. The Cedars, Warlingham, Surrey.
1883. §Fox, Sir Charles Douglas, M.Inst.C.E. 5 Delahay-street, Westminster, S.W.
1860. *Fox, Rev. Edward, M.A. Silverdale, Hassocks, Sussex.
1883. ‡Fox, Howard, F.G.S. Falmouth.
1847. *Fox, Joseph Hoyland. The Cleve, Wellington, Somerset.
1860. ‡*Fox, Joseph John. Lordship-terrace, Stoke Newington, London, N.*
1876. ‡*Fox, St. G. Lane. 9 Sussex-place, London, S.W.*
1888. §Fox, Thomas. Court, Wellington, Somerset.
1886. ‡Foxwell, Arthur, M.A., M.B. 17 Temple-row, Birmingham.
1881. *FOXWELL, HERBERT S., M.A., F.S.S., Professor of Political Economy in University College, London. St. John's College, Cambridge.
1889. ‡Frain, Joseph, M.D. Grosvenor-place, Jesmond, Newcastle-upon-Tyne.
1866. *Francis, G. B. Inglesby, North-road, Hertford.
1884. ‡Francis, James B. Lowell, Massachusetts, U.S.A.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and Manor House, Richmond, Surrey.
1846. ‡FRANKLAND, EDWARD, M.D., D.C.L., LL.D., Ph.D., F.R.S., F.C.S. The Yews, Reigate Hill, Surrey.
1887. *Frankland, Percy F., Ph.D., B.Sc., Professor of Chemistry in University College, Dundee.
1889. ‡Franklin, Rev. Canon. Clayton-street West, Newcastle-upon-Tyne.
1882. ‡Fraser, Alexander, M.B. Royal College of Surgeons, Dublin.
1885. ‡FRASER, ANGUS, M.A., M.D., F.C.S. 232 Union-street, Aberdeen.
1859. ‡Fraser, George B. 3 Airlie-place, Dundee.
Fraser, James William. 8A Kensington Palace-gardens, London, W.
1865. *FRASER, JOHN, M.A., M.D. Chapel Ash, Wolverhampton.
1871. ‡FRASER, THOMAS R., M.D., F.R.S. L. & E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1859. *Frazer, Daniel. 127 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1884. *Frazer, Persifor, M.A., D.Sc., Professor of Chemistry in the Franklin Institute of Pennsylvania. Room 1042, Drexel Buildings, Fifth and Chestnut-streets, Philadelphia, U.S.A.
1884. *FREAM, W., LL.D., B.Sc., F.L.S., F.G.S., F.S.S., Professor of Natural History in the College of Agriculture, Downton, Salisbury.
1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester.
1877. §Freeman, Francis Ford. 8 Leigham-terrace, Plymouth.
1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
1841. Freeth, Major-General S. 30 Royal-crescent, Notting Hill, London, W.
1884. *Fremantle, The Hon. Sir C. W., K.C.B. Royal Mint, London, E.
1869. ‡Frere, Rev. William Edward. The Rectory, Bitton, near Bristol.
1886. ‡Freshfield, Douglas W., Sec.R.G.S. 1 Savile-row, London, W.
1886. ‡Freund, Miss Ida. Eyre Cottage, Upper Sydenham, S.E.
1887. ‡Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.

Year of Election.

1857. **Frith, Richard Hastings, M.R.I.A., F.R.G.S.I.* 48 *Summer-hill, Dublin.*
1887. ‡Froehlich, The Chevalier. Grosvenor-terrace, Withington, Manchester.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1883. ‡Frost, Major H., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. St. James's-chambers, Duke-street, London, S.W.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
1875. *Fry, Joseph Storrs. 2 Charlotte-street, Bristol.
1884. §Fryer, Joseph, J.P. Smelt House, Howden-le-Wear, Co. Durham.
1872. *Fuller, Rev. A. Pallant, Chichester.
1859. ‡FULLER, FREDERICK, M.A. 9 Palace-road, Surbiton.
1869. ‡FULLER, GEORGE, M.Inst.C.E. 71 Lexham-gardens, Kensington, London, W.
1884. §Fuller, William. Oswestry.

1881. ‡Gabb, Rev. James, M.A. Bulmer Rectory, Welburn, Yorkshire.
1887. ‡Gaddum, G. H. Adria House, Toy-lane, Withington, Manchester.
1836. *Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡GAGES, ALPHONSE, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Southwell.
1876. ‡Gairdner, Charles. Broom, Newton Mearns, Renfrewshire.
1850. ‡Gairdner, Professor W. T., M.D. 225 St. Vincent-street, Glasgow.
1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 225 Oxford-street, London, W.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1888. ‡Gallenga, Mrs. Anna. The Falls, Chepstow.
1888. ‡Gallenga, Mrs. A. A. R. The Falls, Chepstow.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
1889. §Galloway, Walter. Eighton Banks, Gateshead.
1875. ‡GALLOWAY, W. Cardiff.
1887. *Galloway, W. The Cottage, Seymour-grove, Old Trafford, Manchester.
1860. *GALTON, Sir DOUGLAS, K.C.B., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. (GENERAL SECRETARY.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *GALTON, FRANCIS, M.A., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. 40 Great Marlborough-street, London, W.
1887. *Galton, Miss Laura Gwendolen Douglas. 12 Chester-street, Grosvenor-place, London, S.W.
1870. §Gamble, Lieut.-Colonel D. St. Helens, Lancashire.
1889. §Gamble, David, jun. St. Helens, Lancashire.
1870. ‡Gamble, J. C. St. Helens, Lancashire.
1888. *Gamble, J. Sykes, M.A., F.L.S. Surbiton.
1877. ‡Gamble, William. St. Helens, Lancashire.
1868. ‡*Gamgee, Arthur, M.D., F.R.S.* 17 *Great Cumberland-place, London, W.*
1889. ‡Gamgee, John. 6 Lingfield-road, Wimbledon, Surrey.
1883. ‡Gant, Major John Castle. St. Leonards.
1887. ‡GARDINER WALTER, M.A., F.R.S., F.L.S. Clare College, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. 25 Northbrook-road, Lee, Kent.
1882. ‡GARDNER, JOHN STARKIE, F.G.S. 7 Damer-terrace, Chelsea, London, S.W.
1884. ‡Garman, Samuel. Cambridge, Massachusetts, U.S.A.

Year of Election.

1862. ‡GARNER, ROBERT, F.L.S. Stoke-upon-Trent.
1865. ‡Garner, Mrs. Robert. Stoke-upon-Trent.
1888. §Garnett, Frederick Brooksbank, C.B. 4 Argyll-road, Campden Hill, London, W.
1887. *Garnett, Jeremiah. The Grange, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L., Principal of the College of Physical Science, Newcastle-on-Tyne.
1873. ‡Garnham, John. Hazelwood, Crescent-road, St. John's, Brockley, Kent, S.E.
1883. §Garson, J. G., M.D. 14 Suffolk-street, Pall Mall, London, S.W.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1882. ‡Garton, William. Woolston, Southampton.
1889. ‡Garwood, E. J. 14 St. Mary's-place, Newcastle-upon-Tyne.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Clayton Lodge, Aigburth, Liverpool.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Place, East Grinstead, Sussex.
1890. §Gaunt, Sir Edwin. Carlton Lodge, Leeds.
1875. ‡Gavey, J. 43 Stacey-road, Routh, Cardiff.
1875. ‡Gaye, Henry S., M.D. Newton Abbot, Devon.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1883. ‡Geddes, John. 33 Portland-street, Southport.
1885. §Geddes, Professor Patrick. 6 James-court, Edinburgh.
1887. ‡Gee, W. W. Haldane. Owens College, Manchester.
1867. ‡GEIKIE, ARCHIBALD, LL.D., For.Sec.R.S., F.R.S.E., Pres.G.S., Director-General of the Geological Survey of the United Kingdom. Geological Survey Office, Jermyn-street, London, S.W.
1871. ‡GEIKIE, JAMES, LL.D., D.C.L., F.R.S. L. & E., F.G.S., Murchison Professor of Geology and Mineralogy in the University of Edinburgh. 31 Merchiston-avenue, Edinburgh.
1882. *GENESE, R. W., M.A., Professor of Mathematics in University College, Aberystwith.
1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1885. ‡Gerard, Robert. Blair-Devenick, Cults, Aberdeen.
1884. *Gerrans, Henry T., M.A. Worcester College, Oxford.
1870. *Gervis, Walter S., M.D., F.G.S. Ashburton, Devonshire.
1884. ‡Gibb, Charles. Abbotsford, Quebec, Canada.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1889. ‡Gibson, Charles, M.D. 8 Eldon-square, Newcastle-upon-Tyne.
1874. ‡Gibson, The Right Hon. Edward, Q.C. 23 Fitzwilliam-square, Dublin.
1876. *Gibson, George Alexander, M.D., D.Sc., F.R.S.E., Secretary to the Royal College of Physicians of Edinburgh. 17 Alva-street, Edinburgh.
1884. ‡Gibson, Rev. James J. 183 Spadina-avenue, Toronto, Canada.
1885. ‡Gibson, John, Ph.D. The University, Edinburgh.
1889. *Gibson, T. G. 2 Eslington-road, Newcastle-upon-Tyne.
1887. ‡GIFFEN, ROBERT, LL.D., V.P.S.S. 44 Pembroke-road, London, S.W.
1888. **Gifford, H. J. Bute Arms, Pontydown, South Wales.*
1884. ‡Gilbert, E. E. 245 St. Antoine-street, Montreal, Canada.
1842. GILBERT, JOSEPH HENRY, Ph.D., LL.D., F.R.S., F.C.S., Professor of Rural Economy in the University of Oxford. Harpenden, near St. Albans.
1883. ‡Gilbert, Mrs. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1884. *Gilbert, Philip H. 456 St. Urbain-street, Montreal, Canada.

Year of Election.

1883. ‡Gilbert, Thomas. Derby-road, Southport.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
1882. ‡Giles, Alfred, M.P., M.Inst.C.E. 26 Great George-street, London, S.W.
1878. ‡Giles, Oliver. Crescent Villas, Bromsgrove.
Giles, Rev. William. Netherleigh House, near Chester.
1878. ‡*Gill, Rev. A. W. H. 44 Eaton-square, London, S.W.*
1871. *GILL, DAVID, LL.D., F.R.S., F.R.A.S. Royal Observatory, Cape Town.
1888. §Gill, John Frederick. Douglas, Isle of Man.
1868. ‡Gill, Joseph. Palermo, Sicily. (Care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.)
1864. ‡GILL, THOMAS. 4 Sydney-place, Bath.
1887. ‡Gillett, Charles Edwin. Wood Green, Banbury, Oxford.
1888. ‡Gilliland, E. T. 259 West Seventy-fourth-street, New York, U.S.A.
1884. ‡Gillman, Henry. 79 East Columbia-street, Detroit, Michigan, U.S.A.
1861. *Gilroy, George. Woodlands, Parbold, near Southport.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1887. *Gimingham, Charles H. Stamford House, Northumberland Park, Tottenham, Middlesex.
1867. ‡GINSBURG, Rev. C. D., D.C.L., LL.D. Holmlea, Virginia Water Station, Chertsey.
1884. ‡Girdwood, Dr. G. P. 28 Beaver Hall-terrace, Montreal, Canada.
1874. *Girdwood, James Kennedy. Old Park, Belfast.
1884. ‡Gisborne, Frederick Newton. Ottawa, Canada.
1886. *Gisborne, Hartley. Qu'Appelle Station, Assa, N.W.T., Canada.
1883. *Gladstone, Miss. 17 Pembridge-square, London, W.
1883. *Gladstone, Miss E. A. 17 Pembridge-square, London, W.
1850. *Gladstone, George, F.C.S., F.R.G.S. 34 Denmark-villas, Hove, Brighton.
1849. *GLADSTONE, JOHN HALL, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, London, W.
1890. *Gladstone, Miss Margaret E. 17 Pembridge-square, London, W.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, London, S.E.
1871. *GLAISHER, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. Trinity College, Cambridge.
1883. ‡Glasson, L. T. 2 Roper-street, Penrith.
1881. *GLAZEBROOK, R. T., M.A., F.R.S. Trinity College, Cambridge.
1887. §Glazier, Walter H., F.C.S. Courtlands, East Molesey, Surrey.
1881. *Gleadow, Frederic. 84 Kensington Park-road, London, W.
1870. §Glen, David Corse, F.G.S. 14 Annfield-place, Glasgow.
1859. ‡Glennie, J. S. Stuart, M.A. The Shealing, Wimbledon Common, Surrey.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1874. ‡Glover, George T. 30 Donegall-place, Belfast.
Glover, Thomas. 124 Manchester-road, Southport.
1887. ‡Glover, Walter T. Moorhurst, Kersal, Manchester.
1870. ‡Glynn, Thomas R., M.D. 62 Rodney-street, Liverpool.
1889. §Goddard, F. R. 19 Victoria-square, Newcastle-upon-Tyne.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1886. ‡Godlee, Arthur. 3 Greenfield-crescent, Edgbaston, Birmingham.
1887. ‡Godlee, Francis. 51 Portland-street, Manchester.
1878. *Godlee, J. Lister. 3 New-square, Lincoln's Inn, London, W.C.
1880. ‡GODMAN, F. DU CANE, F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, London, W.

Year of Election.

1883. ‡Godson, Dr. Alfred. Cheadle, Cheshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. §GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.G.S., F.R.G.S., F.Z.S. Shalford House, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1886. ‡GOLDSMID, Major-General Sir F. J., C.B., K.C.S.I., F.R.G.S. Godfrey House, Hollingbourne.
1881. ‡Goldschmidt, Edward. Nottingham.
1873. ‡Goldthorp, Miss R. F. C. Cleckheaton, Bradford, Yorkshire.
1890. *Gonner, E. C. K., M.A., Professor of Political Economy in University College, Liverpool.
1884. ‡Good, Charles E. 102 St. François Xavier-street, Montreal, Canada.
1878. ‡*Good, Rev. Thomas, B.D. 51 Wellington-road, Dublin.*
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1878. ‡Goodbody, Jonathan, jun. 50 Dame-street, Dublin.
1884. ‡Goodbody, Robert. Fairy Hill, Blackrock, Co. Dublin.
1886. ‡Goodman, F. B. 46 Wheeley's-road, Edgbaston, Birmingham.
1885. ‡GOODMAN, J. D., J.P. Peachfield, Edgbaston, Birmingham.
1865. ‡Goodman, J. D. Minories, Birmingham.
1869. ‡*Goodman, Neville, M.A. Peterhouse, Cambridge.*
1884. *Goodridge, Richard E. W. Oak Bank, Manitoba, Canada.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1883. ‡Goouch, B., B.A. 2 Oxford-road, Birkdale, Southport.
1885. ‡Gordon, General the Hon. Sir Alexander Hamilton. 50 Queen's Gate-gardens, London, S.W.
1885. ‡Gordon, Rev. Cosmo, D.D., F.R.A.S., F.G.S. Chetwynd Rectory, Newport, Salop.
1885. ‡Gordon, Rev. George, LL.D. Birnie, by Elgin, N.B.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's Mansions, Westminster, S.W.
1884. *Gordon, Robert, M.Inst.C.E., F.R.G.S. Fernhill, Henbury, near Bristol.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1885. ‡Gordon, Rev. William. Braemar, N.B.
1887. §Gordon, William John. 3 Lavender-gardens, London, S.W.
1865. ‡Gore, George, LL.D., F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1875. *Gotch, Francis, B.A., B.Sc. Holywell Cottage, Oxford.
*Gotch, Thomas Henry. Kettering.
1873. ‡Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, The Right Hon. George S., Viscount, M.A., F.L.S., F.G.S. St. Helen's, Booterstown, Dublin.
1881. ‡Gough, Thomas, B.Sc., F.C.S. Elmfield College, York.
1868. ‡Gould, Rev. George. Unthank-road, Norwich.
1888. ‡Gouraud, Colonel. Little Menlo, Norwood, Surrey.
1873. ‡Gourlay, J. McMillan. 21 St. Andrew's-place, Bradford, Yorkshire.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. ‡Gow, Robert. Cairndowan, Dowanhill, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill, Glasgow.
Gowland, James. London-wall, London, E.C.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1886. ‡Grabham, Michael C., M.D. Madeira.

Year of Election.

1861. ‡Grafton, Frederick W. Park-road, Whalley Range, Manchester.
1867. *GRAHAM, Sir CYRIL C., Bart., C.M.G., F.L.S., F.R.G.S. Travellers' Club, Pall Mall, London, S.W.
1875. ‡GRAHAME, JAMES. 12 St. Vincent-street, Glasgow.
1852. *GRAINGER, Rev. Canon JOHN, D.D., M.R.I.A. Skerry and Rathcavan Rectory, Broughshane, near Ballymena, Co. Antrim.
1870. ‡GRANT, Colonel JAMES A., C.B., C.S.I., F.R.S., F.L.S., F.R.G.S. 19 Upper Grosvenor-street, London, W.
1855. *GRANT, ROBERT, M.A., LL.D., F.R.S., F.R.A.S., Regius Professor of Astronomy in the University of Glasgow. The Observatory, Glasgow.
1854. ‡GRANTHAM, RICHARD B., M.Inst.C.E., F.G.S. Northumberland-chambers, Northumberland-avenue, London, W.C.
1864. ‡Grantham, Richard F. Northumberland-chambers, Northumberland-avenue, London, W.C.
1887. §Gratrix, Samuel. Alport Town, Manchester.
1881. ‡Graves, E. 22 Trebovir-road, Earl's Court-road, London, S.W.
1887. ‡*Graves, John. Broomhurst, Eccles Old-road, Manchester.*
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1890. §Gray, Professor Andrew, M.A., F.R.S.E. University College, Bangor.
1864. *Gray, Rev. Charles. The Vicarage, Blyth, Rotherham.
1865. ‡Gray, Charles. Swan Bank, Bilston.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1859. ‡*Gray, Rev. J. H. Bolsover Castle, Derbyshire.*
1887. §Gray, Joseph W., F.G.S. Spring Hill, Wellington-road South, Stockport.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1881. ‡Gray, Thomas, Professor of Engineering in the Rane Technical Institute, Terre Haute, Indiana, U.S.A.
1873. ‡Gray, William, M.R.I.A. 8 Mount Charles, Belfast.
*GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1883. ‡Gray, William Lewis. 36 Gutter-lane, London, E.C.
1883. ‡Gray, Mrs. W. L. 36 Gutter-lane, London, E.C.
1886. ‡Greaney, Rev. William. Bishop's House, Bath-street, Birmingham.
1883. ‡Greathead, J. H. 8 Victoria-chambers, London, S.W.
1866. §Greaves, Charles Augustus, M.B., LL.B. 101 Friar-gate, Derby.
1887. ‡Greaves, H. R. The Orchards, Mill End, Stockport.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 3 South-square, Gray's Inn, London, W.C.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1879. ‡*Green, A. F. 15 Ashwood-villas, Headingley, Leeds.*
1889. §GREEN, A. H., M.A., F.R.S., F.G.S., Professor of Geology in the University of Oxford. 137 Woodstock-road, Oxford.
1888. §GREEN, JOSEPH R., M.A., B.Sc., F.L.S., Professor of Botany to the Pharmaceutical Society of Great Britain. 17 Bloomsbury-square, London, W.C.
1887. ‡Greene, Friese. 162 Sloane-street, London, S.W.
1887. ‡Greenhalgh, Richard. 1 Temple-gardens, The Temple, London, E.C.
1858. *Greenhalgh, Thomas. Thornydikes, Sharples, near Bolton-le-Moors.
1882. ‡GREENHILL, A. G., M.A., F.R.S., Professor of Mathematics in the Royal Artillery College, Woolwich. 3 Staple Inn, London, W.C.
1881. §Greenhough, Edward. Matlock Bath, Derbyshire.
1884. ‡Greenish, Thomas, F.C.S. 20 New-street, Dorset-square, London, N.W.
1884. ‡Greenshields, E. B. Montreal, Canada.

Year of Election.

1884. ‡Greenshields, Samuel. Montreal, Canada.
1887. ‡Greenwell, G. C., jun. Poynton, Cheshire.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1889. ‡Greenwell, T. G. Woodside, Sunderland.
1890. §Greenwood, Arthur. Cavendish-road, Leeds.
1875. ‡*Greenwood, Frederick. School of Medicine, Leeds.*
1877. ‡Greenwood, Holmes. 78 King-street, Accrington.
1883. ‡GREENWOOD, J. G., LL.D. 34 Furness-road, Eastbourne.
1849. ‡Greenwood, William. Stones, Todmorden.
1887. §Greenwood, Professor W. H., M.Inst.C.E. Firth College, Sheffield.
1887. *Greg, Arthur. Eagley, near Bolton, Lancashire.
1861. *GREG, ROBERT PHILIPS, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1833. Gregg, T. H. 12 Alexandra-road, Finsbury Park, London, N.
1860. ‡GREGOR, Rev. WALTER, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Sir Charles Hutton, K.C.M.G., M.Inst.C.E. 2 Delahay-street, Westminster, S.W.
1883. ‡Gregson, Edward, Ribble View, Preston.
1883. ‡Gregson, G. E. Ribble View, Preston.
1881. ‡Gregson, William. Baldersby, Thirsk.
1875. ‡Grenfell, J. Granville, B.A., F.G.S. 55 West Cromwell-road, London, S.W.
1859. ‡GRIERSON, THOMAS BOYLE, M.D. Thornhill, Dumfries-shire.
1870. ‡Grieve, John, M.D. Care of W. L. Buchanan, Esq., 212 St. Vincent-street, Glasgow.
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
1859. *GRIFFITH, GEORGE, M.A., F.C.S. (ASSISTANT GENERAL SECRETARY.) Druries, Harrow.
1870. ‡Griffith, Rev. Henry, F.G.S. Brooklands, Isleworth, Middlesex.
1884. ‡Griffiths, E. H. 12 Park-side, Cambridge.
1884. ‡Griffiths, Mrs. 12 Park-side, Cambridge.
1847. ‡Griffiths, Thomas. Bradford-street, Birmingham.
1879. ‡Griffiths, Thomas, F.C.S., F.S.S. Heidelberg House, King's-road, Clapham Park, London, S.W.
1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1888. *Grimshaw, James Walter. Australian Club, Sydney, New South Wales.
1884. ‡Grinnell, Frederick. Providence, Rhode Island, U.S.A.
1881. ‡Gripper, Edward. Nottingham.
1864. ‡GROOM-NAPIER, CHARLES OTTLEY. 18 Elgin-road, St. Peter's Park, London, N.W.
GROVE, The Hon. Sir WILLIAM ROBERT, Knt., M.A., D.C.L., LL.D., F.R.S. 115 Harley-street, London, W.
1863. *GROVES, THOMAS B., F.C.S. 80 St. Mary-street, Weymouth.
1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. 51 Kenilworth-square, Rathgar, Dublin.
1886. §Grundy, John. Park Drive, Nottingham.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
1887. ‡GUILLEMARD, F. H. H. Eltham, Kent.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1885. ‡Gunn, John. Dale, Halkirk, Caithness.
1877. ‡Gunn, William, F.G.S. Office of the Geological Survey of Scotland, Sheriff's Court House, Edinburgh.
1866. ‡GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., Keeper of the Zoological Collections in the British Museum. British Museum, South Kensington, London, S.W.

Year of Election.

1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1876. ‡Guthrie, Francis. Cape Town, Cape of Good Hope.
1883. ‡Guthrie, Malcolm. 2 Parkfield-road, Liverpool.
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1876. ‡Gwyther, R. F., M.A. Owens College, Manchester.

1884. ‡Haanel, E., Ph.D. Cobourg, Ontario, Canada.
1887. ‡Hackett, Henry Eugene. Hyde-road, Gorton, Manchester.
1865. ‡Hackney, William. 9 Victoria-chambers, Victoria-street, London, S.W.
1884. ‡Hadden, Captain C. F., R.A. Woolwich.
1881. *Haddon, Alfred Cort, B.A., F.Z.S., Professor of Zoology in the Royal College of Science, Dublin.
Haden, G. N. Trowbridge, Wiltshire.
1842. Hadfield, George. Victoria-park, Manchester.
1888. *Hadfield, R. A. Hecla Works, Sheffield.
1870. ‡Haigh, George. Waterloo, Liverpool.
1879. ‡Hake, H. Wilson, Ph.D., F.C.S. Queenwood College, Hants.
1875. ‡Hale, Rev. Edward, M.A., F.G.S., F.R.G.S. Eton College, Windsor.
1887. ‡Hale, The Hon. E. J. 9 Mount-street, Manchester.
1883. ‡*Haliburton, Robert Grant. National Club, Whitehall, London, S.W.*
1872. ‡*Hall, Dr. Alfred. 8 Mount Ephraim, Tunbridge Wells.*
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. *Hall, Miss Emily. Burlington House, Spring Grove, Isleworth, Middlesex.
1881. ‡Hall, Frederick Thomas, F.R.A.S. 15 Gray's Inn-square, London, W.C.
1854. *Hall, Hugh Fergie, F.G.S. Fau-y-Bryn, Llandudno.
1887. ‡Hall, John. Springbank, Leftwich, Northwich.
1872. *Hall, Captain Marshall, F.G.S. St. John's, Bovey Tracey, South Devon.
1885. §Hall, Samuel. 19 Aberdeen Park, Highbury, London, N.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1866. *Hall, Townshend M., F.G.S. Orchard House, Pilton, Barnstaple.
1873. *Hallett, T. G. P., M.A. Claverton Lodge, Bath.
1868. *Hallett, William Henry, F.L.S. Buckingham House, Marine Parade, Brighton.
1888. §Halliburton, W. D., M.D. 25 Maitland Park-villas, London, N.W.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1886. §Hambleton, G. W. 54a York-street, Portman-square, London, W.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Holmeside, Hazelwood, Derby.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1885. ‡Hamilton, David James. 1a Albyn-place, Aberdeen.
1869. ‡Hamilton, Rowland. Oriental Club, Hanover-square, London, W.
1888. *Hammond, Anthony, J.P. Bath.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1881. *Hammond, Robert. Hilldrop, Highgate, London, N.
1878. ‡Hanagan, Anthony. Luckington, Dalkey.
1878. §Hance, Edward M., LL.B. 15 Pelham-grove, Sefton Park, Liverpool.
1875. ‡Hancock, C. F., M.A. 125 Queen's-gate, London, S.W.
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, London, E.C.
1857. ‡Hancock, William J. 23 Synnot-place, Dublin.
1876. ‡Hancock, Mrs. W. Neilson. 64 Upper Gardiner-street, Dublin.
1890. §Hankin, Ernest Hanbury. St. John's College, Cambridge.

Year of Election.

1882. ‡Hankinson, R. C. Bassett, Southampton.
1884. §Hannaford, E. C. 1591 Catherine-street, Montreal, Canada.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1886. §Hansford, Charles. 3 Alexandra-terrace, Dorchester.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., F.R.S., F.C.S. (GENERAL SECRETARY.) Cowley Grange, Oxford.
1890. *Harcourt, L. F. Vernon, M.Inst.C.E. 6 Queen Anne's-gate, London, S.W.
1886. *Hardcastle, Basil W., F.S.S. Beechenden, Hampstead, London, N.W.
1884. *Hardcastle, Norman C., M.A., LL.D. Downing College, Cambridge.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Millbrook House, Exeter.
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1886. ‡Hardman, John B. St. John's, Hunter's-lane, Birmingham.
1880. ‡Hardy, John. 118 Embden-street, Manchester.
1838. *HARE, CHARLES JOHN, M.D. Berkeley House, 15 Manchester-square, London, W.
1858. ‡Hargrave, James. Burley, near Leeds.
1883. ‡Hargreaves, Miss H. M. 69 Alexandra-road, Southport.
1883. ‡Hargreaves, Thomas. 69 Alexandra-road, Southport.
1890. §Hargrove, Rev. Charles. 10 De Grey-terrace, Leeds.
1881. †Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. §Harker, Alfred. St. John's College, Cambridge.
1876. ‡Harker, Allen, F.L.S., Professor of Natural History in the Royal Agricultural College, Cirencester.
1887. ‡Harker, T. H. Brook House, Fallowfield, Manchester.
1878. *Harkness, H. W. California Academy of Sciences, San Francisco, California, U.S.A.
1871. ‡Harkness, William, F.C.S. Laboratory, Somerset House, London, W.C.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton, Sussex.
1883. *Harley, Miss Clara. 4 Wellington-square, Oxford.
1862. *HARLEY, GEORGE, M.D., F.R.S., F.C.S. 25 Harley-street, London, W.
1883. *Harley, Harold. 14 Chapel-street, Bedford-row, London, W.C.
1862. *HARLEY, Rev. ROBERT, M.A., F.R.S., F.R.A.S. 4 Wellington-square, Oxford.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *HARMER, SIDNEY F., M.A., B.Sc. King's College, Cambridge.
1882. ‡Harper, G. T. Bryn Hyfrydd, Portswood, Southampton.
1872. ‡Harpley, Rev. William, M.A. Clayhanger Rectory, Tiverton.
1884. ‡Harrington, B. J., B.A., Ph.D., Professor of Chemistry and Mineralogy in McGill University, Montreal. Wallbrac-place, Montreal, Canada.
1872. *Harris, Alfred. Lunefield, Kirkby Lonsdale, Westmoreland.
1888. ‡Harris, C. T. 4 Kilburn Priory, London, N.W.
1871. ‡HARRIS, GEORGE, F.S.A. Iselipps Manor, Northolt, Southall, Middlesex.
1842. *Harris, G. W., M.Inst.C.E. Mount Gambier, South Australia.
1889. §HARRIS, H. GRAHAM, M.Inst.C.E. 5 Great George-street, Westminster, S.W.
1884. ‡Harris, Miss Katherine E. 73 Albert Hall-mansions, Kensington-gore, London, S.W.
1888. ‡Harrison, Charles. 20 Lennox-gardens, London, S.W.

Year of Election.

1860. ‡Harrison, Rev. Francis, M.A. North Wraxall, Chippenham.
1864. ‡Harrison, George. Barnsley, Yorkshire.
1874. ‡Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.
1858. *Harrison, James Park, M.A. 22 Connaught-street, Hyde Park, London, W.
1889. §Harrison, J. C. Oxford House, Castle-road, Scarborough.
1870. ‡Harrison, Reginald, F.R.C.S. 6 Lower Berkeley-street, Portman-square, London, W.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1883. ‡*Harrison, Thomas.* 34 *Ash-street, Southport.*
1886. §Harrison, William. The Horsehills, Wolverhampton.
1886. ‡Harrison, W. Jerome, F.G.S. 365 Lodge-road, Hockley, Birmingham.
1885. ‡Hart, Charles J. 10 Calthorpe-road, Edgbaston, Birmingham.
1876. *Hart, Thomas. Brooklands, Blackburn.
1881. §Hart, Thomas, F.G.S. Yewbarrow, Grange-over-Sands, Carnforth.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
Hartley, James. Sunderland.
1871. ‡Hartley, Walter Noel, F.R.S. L. & E., F.C.S., Professor of Chemistry in the Royal College of Science, Dublin.
1890. *Hartnell, Wilson. 8 Blenheim-terrace, Leeds.
1886. *Hartog, Professor M. M., D.Sc. Queen's College, Cork.
1887. §Hartog, P. J., B.Sc. 6 Greville-road, London, N.W.
1870. ‡Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.
1885. ‡Harvey, Surgeon-Major Robert, M.D. Calcutta.
1885. §Harvie-Brown, J. A. Dunipace, Larbert, N.B.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-Moors.
1884. ‡Haslam, Rev. George, M.A. Trinity College, Toronto, Canada.
1882. ‡Haslam, George James, M.D. Owens College, Manchester.
1875. *Hastings, G. W., M.P. Barnard's Green House, Malvern.
1889. §Hatch, Dr. F. H., F.G.S. 28 Jermyn-street, London, S.W.
1857. ‡Haughton, Rev. Samuel, M.A., M.D., D.C.L., LL.D., F.R.S., M.R.I.A., F.G.S., Senior Fellow of Trinity College, Dublin. Trinity College, Dublin.
1887. *Hawkins, William. 11 Fountain-street, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, London, S.W.
*Hawkshaw, Sir John, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Hollycombe, Liphook, Petersfield; and 33 Great George-street, London, S.W.
1864. *Hawkshaw, John Clarke, M.A., M.Inst.C.E., F.G.S. 50 Harrington-gardens, South Kensington, S.W.; and 33 Great George-street London, S.W.
1868. ‡Hawksley, Thomas, M.Inst.C.E., F.R.S., F.G.S. 30 Great George-street, London, S.W.
1884. *Haworth, Abraham. Hilston House, Altrincham.
1889. §Haworth, George C. Ordsal-lane, Salford.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1887. ‡Haworth, S. E. Warsley-road, Swinton, Manchester.
1886. ‡Haworth, Rev. T. J. Albert Cottage, Saltley, Birmingham.
1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1890. §Hawtin, J. N. Sturdie House, Roundhay-road, Leeds.
1877. ‡Hay, Arthur J. Lerwick, Shetland.
1861. *Hay, Admiral the Right Hon. Sir John C. D., Bart., K.C.B., D.C.L., F.R.S. 108 St. George's-square, London, S.W.
1867. ‡Hay, William. 21 Magdalen-yard-road, Dundee.
1885. *Haycraft, Professor John Berry, M.B., B.Sc., F.R.S.E. Physiological Laboratory, The University, Edinburgh.

Year of Election.

1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1869. ‡Hayward, J. High-street, Exeter.
1858. *HAYWARD, ROBERT BALDWIN, M.A., F.R.S. Harrow.
1888. ‡Hazard, Rowland R. Little Mulgrave House, Hurlingham.
1879. **Hazlehurst, George S. Rhyl, North Wales.*
1851. §HEAD, JEREMIAH, M.Inst.C.E., F.C.S. Middlesbrough, Yorkshire.
1869. ‡*Head, R. T. The Briars, Alphington, Exeter.*
1883. ‡Headley, Frederick Halcombe. Manor House, Petersham, S.W.
1883. ‡Headley, Mrs. Marian. Manor House, Petersham, S.W.
1883. §Headley, Rev. Tanfield George. Manor House, Petersham, S.W.
1871. §Healey, George. Brantfield, Bowness, Windermere.
1883. *Heap, Ralph, jun. 1 Brick-court, Temple, London, E.C.
1861. *Heape, Benjamin. Northwood, Prestwich, Manchester.
1883. ‡Heape, Charles. Tovrak, Oxton, Cheshire.
1883. ‡Heape, Joseph R. 96 Tweedale-street, Rochdale.
1882. *Heape, Walter, M.A. Northwood, Prestwich, Manchester.
1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1877. ‡Hearder, William Keep, F.S.A. 195 Union-street, Plymouth.
1883. ‡Heath, Dr. 46 Hoghton-street, Southport.
1889. ‡Heath, Dr. Westgate-road, Newcastle-upon-Tyne.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
1884. ‡Heath, Thomas, B.A. Royal Observatory, Calton Hill, Edinburgh.
1861. ‡HEATHFIELD, W. E., F.C.S., F.R.G.S., F.R.S.E. 1 Powis-grove, Brighton; and Arthur's Club, St. James's, London, S.W.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1886. ‡Heaton, C. W. 44 Woodstock-road, Bedford Park, London, W.
1886. ‡Heaton, Miss Ellen. Woodhouse-square, Leeds.
1865. ‡Heaton, Harry. Harborne House, Harborne, near Birmingham.
1889. *Heaviside, Arthur West. 7 Grafton-road, Whitley, Newcastle-upon-Tyne.
1884. §Heaviside, Rev. George, B.A., F.R.G.S., F.R.Hist.S. The Hollies, Stoke, Coventry.
1833. ‡HEAVISIDE, Rev. Canon J. W. L., M.A. The Close, Norwich.
1888. *Heawood, Edward, B.A., F.G.S. 41 Old Elvet, Durham.
1888. *Heawood, Percy Y., Lecturer in Mathematics at Durham University. 41 Old Elvet, Durham.
1855. ‡HECTOR, Sir JAMES, K.C.M.G., M.D., F.R.S., F.G.S., F.R.G.S., Director of the Geological Survey of New Zealand. Wellington, New Zealand.
1867. ‡Heddle, M. Forster, M.D., F.R.S.E. St. Andrews, N.B.
1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.
1882. ‡Hedger, Philip. Cumberland-place, Southampton.
1887. *Hedges, Killingworth, M.Inst.C.E. 25 Queen Anne's-gate, London, S.W.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-upon-Tyne.
1887. §Hembry, Frederick William, F.R.M.S. Sussex Lodge, Sidcup, Kent.
1867. ‡Henderson, Alexander. Dundee.
1873. *Henderson, A. L. 277 Lewisham High-road, London, S.E.
1883. ‡Henderson, Mrs. A. L. 277 Lewisham High-road, London, S.E.
1880. *Henderson, Captain W. H., R.N. 21 Albert Hall Mansions, London, S.W.
1876. *Henderson, William. Williamfield, Irvine, N.B.
1885. ‡Henderson, William. Devanha House, Aberdeen.
1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A., Professor of Applied Mathematics and Mechanics in the Royal College of Science for Ireland. Brookvale, Donnybrook, Co. Dublin.

Year of Election.

1857. ‡Hennessy, Sir John Pope, K.C.M.G., M.P. House of Commons, London, S.W.

1873. *Henrici, Olaus M. F. E., Ph.D., F.R.S., Professor of Mechanics and Mathematics in the City and Guilds of London Institute. Central Institution, Exhibition-road, London, S.W.

Henry, Franklin. Portland-street, Manchester.

1873. Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.

Henry, Mitchell. Stratheden House, Hyde Park, London, W.

*Henry, William Charles, M.D., F.R.S., F.G.S., F.R.G.S., F.C.S. Haffield, near Ledbury, Herefordshire.

1884. ‡Henshaw, George H. 43 Victoria-street, Montreal, Canada.

1870. ‡*Henty, William. 12 Medina-villas, Brighton.*

1855. *Hepburn, J. Gotch, LL.B., F.C.S. Dartford, Kent.

1855. ‡Hepburn, Robert. 9 Portland-place, London, W.

1890. §Hepper, J. 43 Cardigan-road, Headingley, Leeds.

1890. §Hepworth, Joseph. 25 Wellington-street, Leeds.

1887. *Herdman, William A., D.Sc., Professor of Natural History in University College, Liverpool.

1871. *Herschel, Alexander S., M.A., D.C.L., F.R.S., F.R.A.S., Honorary Professor of Physics and Experimental Philosophy in the University of Durham College of Science, Newcastle-on-Tyne. Observatory House, Slough, Bucks.

1874. §Herschel, Colonel John, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.

1890. §Hewetson, H. Bendelack, M.R.C.S., F.L.S. 11 Hanover-square, Leeds.

1884. §Hewett, George Edwin. Cotswold House, St. John's Wood Park, London, N.W.

1883. ‡Hewson, Thomas. Care of J. C. C. Payne, Esq., Botanic-avenue, The Plains, Belfast.

1881. ‡Hey, Rev. William Croser, M.A. Clifton, York.

1882. ‡Heycock, Charles T., B.A. King's College, Cambridge.

1883. §Heyes, Rev. John Frederick, M.A., F.C.S., F.R.G.S. 9 King-street, Oxford.

1866. *Heymann, Albert. West Bridgford, Nottinghamshire.

1879. ‡Heywood, A. Percival. Duffield Bank, Derby.

1861. *Heywood, Arthur Henry. Elleray, Windermere.

1886. §Heywood, Henry. Cardiff.

*Heywood, James, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S. 26 Kensington Palace-gardens, London, W.

1861. *Heywood, Oliver, J.P., D.L. Claremont, Manchester.

1887. ‡Heywood, Robert. Mayfield, Victoria Park, Manchester.

Heywood, Thomas Percival. Claremont, Manchester.

1888. §Hichens, James Harvey, M.A., F.G.S. The College, Cheltenham.

1881. §Hick, Thomas, B.A., B.Sc. Brighton Grove, Rusholme, Manchester.

1875. ‡Hicks, Henry, M.D., F.R.S., Sec.G.S. Hendon Grove, Hendon, Middlesex, N.W.

1877. §Hicks, Professor W. M., M.A., F.R.S., Principal of Firth College, Sheffield. Firth College, Sheffield.

1886. ‡Hicks, Mrs. W. M. Duvheved, Endcliffe-crescent, Sheffield.

1884. ‡Hickson, Joseph. 272 Mountain-street, Montreal, Canada.

1887. *Hickson, Sydney J., M.A., D.Sc. 16 Elsworthy-road, Primrose Hill, London, N.W.

1864. *Hiern, W. P., M.A. Castle House, Barnstaple.

1875. ‡Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.

Year of Election.

1871. ‡Higgins, Clement, B.A., F.C.S. 103 Holland-road, Kensington, London, W.
1854. ‡Higgins, Rev. Henry H., M.A. 29 Falkner-square, Liverpool.
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
1885. *Hill, Alexander, M.A., M.D. Downing College, Cambridge.
Hill, Arthur. Bruce Castle, Tottenham, Middlesex.
1883. ‡Hill, Berkeley, M.B., Professor of Clinical Surgery in University College, London. 66 Wimpole-street, London, W.
1872. §Hill, Charles, F.S.A. Rockhurst, West Hoathley, East Grinstead.
1881. §Hill, Rev. Edwin, M.A., F.G.S. The Rectory, Cockfield R.S.O., Suffolk.
1887. ‡Hill, G. H. Albert-chambers, Albert-square, Manchester.
1884. ‡Hill, Rev. James Edgar, M.A., B.D. 2488 St. Catherine-street, Montreal, Canada.
1857. §Hill, John, M.Inst.C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.
1886. ‡Hill, M. J. M., D.Sc., Professor of Pure Mathematics in University College, London. 16 Pembury-road, Lower Clapton, London, E.
1881. ‡Hill, Pearson. 50 Belsize Park, London, N.W.
1872. *Hill, Rev. Canon, M.A., F.G.S. Sheering Rectory, Harlow.
1885. *Hill, Sidney. Langford House, Langford, Bristol.
1888. ‡Hill, William. Hitchin, Herts.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1885. *Hillhouse, William, M.A., F.L.S., Professor of Botany in Mason Science College, Birmingham. 95 Harborne-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, Bedford.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1871. *Hills, Thomas Hyde. 225 Oxford-street, London, W.
1887. ‡Hilton, Edwin. Oak Bank, Fallowfield, Manchester.
1858. ‡Hincks, Rev. Thomas, B.A., F.R.S. Stokeleigh, Leigh Woods, Clifton, Bristol.
1870. ‡Hinde, G. J., Ph.D., F.G.S. Avondale-road, Croydon, Surrey.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1888. *Hindmarsh, William Thomas, F.L.S. Alnbank, Alnwick.
1886. ‡Hingley, Benjamin, M.P. Hatherton Lodge, Cradley, Worcestershire.
1881. ‡Hingston, J. T. Clifton, York.
1884. ‡Hingston, William Hales, M.D., D.C.L. 37 Union-avenue Montreal, Canada.
1884. ‡Hirschfilder, C. A. Toronto, Canada.
1890. *Hirst, James Andus. Adel Tower, Leeds.
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1861. *Hirst, T. Archer, Ph.D., F.R.S., F.R.A.S. 7 Oxford and Cambridge Mansions, Marylebone-road, London, N.W.
1884. ‡Hoadrey, John Chipman. Boston, Massachusetts, U.S.A.
Hoare, J. Gurney. Hampstead, London, N.W.
1881. §Hobbes, Robert George. Livingstone House, 374 Wandsworth-road, London, S.W.
1864. ‡*Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.*
1864. ‡*Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.*
1864. ‡*Hobhouse, Henry William. 24 Cadogan-place, London, S.W.*
1879. §Hobkirk, Charles P., F.L.S. West Riding Union Bank, Dewsbury.
1887. *Hobson, Bernard, B.Sc. Tapton Elms, Sheffield.
1883. ‡Hobson, Rev. E. W. 55 Albert-road, Southport.
1877. ‡Hockin, Edward. Poughill, Stratton, Cornwall.

Year of
Election.

1883. ‡Hocking, Rev. Silas K. 21 Scarisbrick New-road, Southport.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *Hodgkin, Thomas, B.A., D.C.L. Benwell Dene, Newcastle-upon-Tyne.
1887. *Hodgkinson, Alexander. 18 St. John-street, Manchester.
1880. §Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 75 Vanbrugh Park, Blackheath, London, S.E.
1873. *Hodgson, George. Thornton-road, Bradford, Yorkshire.
1884. ‡Hodgson, Jonathan. Montreal, Canada.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. 7 Sandhill, Newcastle-upon-Tyne.
1889. ‡Hoey, D. G. 8 Gordon-street, Glasgow.
1865. *Hofmann, August Wilhelm, M.D., LL.D., Ph.D., F.R.S., F.C.S. 10 Dorotheen-strasse, Berlin.
1854. *Holcroft, George. Tyddyn-Gwladis, Ganllwyd, near Dolgelly, North Wales.
1883. ‡Holden, Edward. Laurel Mount, Shipley, Yorkshire.
1873. *Holden, Isaac, M.P. Oakworth House, near Keighley, Yorkshire.
1883. ‡Holden, James. 12 Park-avenue, Southport.
1883. ‡Holden, John J. 23 Duke-street, Southport.
1884. ‡Holden, Mrs. Mary E. Dunham Ladies' College, Quebec, Canada.
1857. *Holder, Henry William, M.A. Owens College, Manchester.
1887. *Holdsworth, C. J. Oxenholme, Westmoreland.
1879. ‡Holland, Calvert Bernard. Ebbw Vale, South Wales.
*Holland, Philip H. 3 Heath-rise, Willow-road, Hampstead, London, N.W.
1889. §Hollander, Bernard. Unionist Club, 68 Pall Mall, London, S.W.
1886. ‡Holliday, J. R. 101 Harborne-road, Birmingham.
1865. ‡Holliday, William. New-street, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring Grove, Isleworth, Middlesex.
1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 59 London-road, Derby.
1873. ‡Holmes, J. R. Southbrook Lodge, Bradford, Yorkshire.
1889. ‡Holmes, Ralph, B.A. Hulme Grammar School, Manchester.
1882. *Holmes, Thomas Vincent, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1887. §Holt, Thomas. Atlas Iron Works, Molesworth-street, Rochdale.
1891. *Hood, Archibald, M.Inst.C.E. 42 Newport-road, Cardiff.
1875. *Hood, John. Chesterton, Cirencester.
1847. ‡Hooker, Sir Joseph Dalton, K.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. The Camp, Sunningdale.
1865. *Hooper, John P. Coventry Park, Streatham, London, S.W.
1877. *Hooper, Rev. Samuel F., M.A. The Vicarage, Blackheath Hill, Greenwich, S.E.
1856. ‡Hooton, Jonathan. 116 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. 14 Airlie-gardens, Campden Hill, London, W.
1884. *Hopkins, Edward M. 3 Upper Berkeley-street, Portman-square, London, W.
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1884. *Hopkinson, Charles. 29 Princess-street, Manchester.
1882. *Hopkinson, Edward, D.Sc. Ireton Bank, Platt-lane, Rusholme, Manchester.
1870. *Hopkinson, John, M.A., D.Sc., F.R.S. Holmwood, Wimbledon, Surrey.

Year of Election.

1871. *HOPKINSON, JOHN, F.L.S., F.G.S., F.R.Met.Soc. 95 New Bond-street, London, W.; and The Grange, St. Albans.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.
1886. ‡Horne, Edward H. Innisfail, Beulah Hill, Norwood, S.E.
1885. ‡Horne, John, F.R.S.E., F.G.S. 41 Southside-road, Inverness.
1876. *Horne, Robert R. 150 Hope-street, Glasgow.
1875. *Horniman, F. J., F.R.G.S., F.L.S. Surrey Mount, Forest Hill, London, S.E.
1884. *Horsfall, Richard. Stoodley House, Halifax.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1884. *Hotblach, G. S. Prince of Wales-road, Norwich.
1868. ‡Hotson, W. C. Upper King-street, Norwich.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1886. ‡Houghton, F. T. S., M.A. 119 Gough-road, Edgbaston, Birmingham.
1887. ‡Houldsworth, Sir W. H., Bart., M.P. Norbury Booths, Knutsford.
1858. ‡*Hounsfield, James. Hemsworth, Pontefract.*
1884. ‡Houston, William. Legislative Library, Toronto, Canada.
1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, Surrey, S.E.
Hovenden, W. F., M.A. Bath.
1879. *Howard, D. 60 Belsize Park, London, N.W.
1883. ‡Howard, James Fielden, M.D., M.R.C.S. Sandycroft, Shaw.
1886. §Howard, James L., D.Sc. 20 Oxford-road, Waterloo, near Liverpool.
1887. *Howard, S. S. Llanishen Rise, near Cardiff.
1882. ‡Howard, William Frederick, Assoc.M.Inst.C.E. 13 Cavendish-street, Chesterfield, Derbyshire.
1883. ‡Howarth, Richard. York-road, Birkdale, Southport.
1886. ‡Howatt, David. 3 Birmingham-road, Dudley.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1885. ‡Howden, James C., M.D. Sunnyside, Montrose, N.B.
1889. §Howden, Robert, M.B. Durham College of Medicine, Newcastle-upon-Tyne.
1857. ‡Howell, Henry H., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh.
1887. ‡Howell, J. A. Edward-street, Werneth, Oldham.
1868. ‡HOWELL, Rev. Canon HINDS. Drayton Rectory, near Norwich.
1886. §HOWES, Professor G. B., F.L.S. Royal College of Science, South Kensington, London, S.W.
1884. ‡Howland, Edward P., M.D. 211 41½-street, Washington, U.S.A.
1884. ‡Howland, Oliver Aiken. Toronto, Canada.
1865. *HOWLETT, Rev. FREDERICK, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡HOWORTH, H. H., M.P., F.S.A. Bentcliffe, Eccles, Manchester.
1883. ‡Howorth, John, J.P. Springbank, Burnley, Lancashire.
1883. ‡Hoyle, James. Blackburn.
1887. §HOYLE, WILLIAM E., M.A. Owens College, Manchester.
1888. §Hudd, Alfred E., F.S.A. 94 Pembroke-road, Clifton, Bristol.
1888. ‡Hudson, C. T., M.A., LL.D., F.R.S. 6 Royal York-crescent, Clifton, Bristol.
1867. *HUDSON, WILLIAM H. H., M.A., Professor of Mathematics in King's College, London. 15 Altenberg-gardens, Clapham Common, London, S.W.
1858. *HUGGINS, WILLIAM, D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. (PRESIDENT ELECT). 90 Upper Tulse Hill, Brixton, London, S.W.

Year of Election.

1887. ‡Hughes, E. G. 4 Roman-place, Higher Broughton, Manchester.
1883. ‡Hughes, Miss E. P. Newnham College, Cambridge.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1887. ‡Hughes, John Taylor. Thorleymoor, Ashley-road, Altrincham.
1870. *Hughes, Lewis. Fenwick-court, Liverpool.
1876. *Hughes, Rev. Thomas Edward. Wallfield House, Reigate.
1868. §HUGHES, T. M'K., M.A., F.R.S., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
1883. ‡HULKE, JOHN WHITAKER, F.R.S., F.R.C.S., F.G.S. 10 Old Burlington-street, London, W.
1867. §HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1887. *Hummel, Professor J. J. Yorkshire College, Leeds.
1890. §Humphrey, Frank W. 63 Prince's-gate, London, S.W.
1884. *Humphreys, A. W. 45 William-street, New York, U.S.A.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *HUMPHRY, Sir GEORGE MURRAY, M.D., F.R.S., Professor of Surgery in the University of Cambridge. Grove Lodge, Cambridge.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1886. ‡Hunt, Charles. The Gas Works, Windsor-street, Birmingham.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1884. ‡HUNT, T. STERRY, M.A., D.Sc., LL.D., F.R.S. Park Avenue Hotel, New York, U.S.A.
1864. ‡Hunt, W. Folkestone.
1875. *Hunt, William. Northcote, Westbury-on-Trym, Bristol.
1881. ‡Hunter, F. W. Newbottle, Fence Houses, Co. Durham.
1889. ‡Hunter, Mrs. F. W. Newbottle, Fence Houses, Co. Durham.
1881. ‡Hunter, Rev. John. University-gardens, Glasgow.
1884. *Hunter, Michael, jun. Greystones, Sheffield.
1869. *Hunter, Rev. Robert. LL.D., F.G.S. Forest Retreat, Staples-road, Loughton, Essex.
1879. ‡HUNTINGTON, A. K., F.C.S., Professor of Metallurgy in King's College, London. King's College, London, W.C.
1885. ‡Huntly, The Most Hon. the Marquis of. Aboyne Castle, Aberdeenshire.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1883. *Hurst, Charles Herbert. Owens College, Manchester.
1869. ‡Hurst, George. Bedford.
1882. ‡Hurst, Walter, B.Sc. West Lodge, Todmorden.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
Husband, William Dalla. The Roost, Miles-road, Clifton, Bristol.
1887. ‡Husband, W. E. 56 Bury New-road, Manchester.
1882. ‡Hussey, Captain E. R., R.E. 24 Waterloo-place, Southampton.
1876. ‡Hutchinson, John. 22 Hamilton Park-terrace, Glasgow.
1868. *Hutchison, Robert, F.R.S.E. University Club, Princes-street, Edinburgh.
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.

Year of Election.

1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, London, N.W.
1857. ‡Hutton, Henry D. 17 Palmerston-road, Dublin.
1887. *Hutton, J. Arthur. 29 Dale-street, Manchester.
1861. *HUTTON, T. MAXWELL. Summerhill, Dublin.
1852. ‡HUXLEY, THOMAS HENRY, Ph.D., LL.D., D.C.L., F.R.S., F.L.S., F.G.S., Professor of Biology in the Royal College of Science, London. Hodeslea, Eastbourne.
Hyde, Edward. Dukinfield, near Manchester.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Stroud, Gloucestershire.

1882. *I'Anson, James, F.G.S. Fairfield House, Darlington.
Ihne, William, Ph.D. Heidelberg.
1884. §Iles, George. 7 Brunswick-street, Montreal, Canada.
1885. ‡im-Thurn, Everard F. British Guiana.
1888. *Ince, Surgeon-Major John, M.D. Montague House, Swanley, Kent.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1871. ‡INGLIS, The Right Hon. JOHN, D.C.L., LL.D., Lord Justice-General of Scotland. Edinburgh.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Librarian to the University of Dublin. 2 Wellington-road, Dublin.
1885. ‡Ingram, William, M.A. Gamrie, Banff.
1886. ‡Innes, John. The Limes, Alcester-road, Moseley, Birmingham.
1882. §IRVING, Rev. A., B.A., D.Sc., F.G.S. Wellington College, Wokingham, Berks.
1888. §Isaac, J. F. V. Freshford House, Freshford, Bath.
1883. ‡Isherwood, James. 18 York-road, Birkdale, Southport.
1881. ‡Ishiguro, Isoji. Care of the Japanese Legation, 9 Cavendish-square, London, W.
1887. §Ito, Tokutaro. 83 Hichikenchio Nichômé, Nagoya, Aichiken, Japan.
1886. ‡Izod, William. Church-road, Edgbaston, Birmingham.

1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1884. ‡Jack, Peter. People's Bank, Halifax, Nova Scotia, Canada.
1876. *Jack, William, LL.D., Professor of Mathematics in the University of Glasgow. 10 The College, Glasgow.
1883. *JACKSON, Professor A. H., B.Sc., F.C.S. Care of Messrs. Wm. Bowen & Co., Collins-street, Melbourne, Australia.
1879. ‡Jackson, Arthur, F.R.C.S. Wilkinson-street, Sheffield.
1883. ‡Jackson, Mrs. Esther. 16 East Park-terrace, Southampton.
1883. ‡Jackson, Frank. 11 Park-crescent, Southport.
1883. *Jackson, F. J. 1 Morley-road, Southport.
1883. ‡Jackson, Mrs. F. J. 1 Morley-road, Southport.
1874. *Jackson, Frederick Arthur. Belmont, Lyme Regis, Dorset.
1886. §Jackson, George. Clareen, Higher Warberry, Torquay.
1887. *Jackson, George. 53 Elizabeth-street, Cheetham, Manchester.
1885. ‡Jackson, Henry. 19 Golden-square, Aberdeen.
1866. ‡Jackson, H. W., F.R.A.S., F.G.S. 67 Upgate, Louth, Lincolnshire.
1869. §Jackson, Moses. Lansdowne House, Tonbridge.
1863. *Jackson-Gwilt, Mrs. H. Moonbeam Villa, The Grove, New Wimbledon, Surrey.
1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.

Year of
Election.

1874. *Jaffe, John. Edenvale, Strandtown, near Belfast.
1865. *Jaffray, John. Park-grove, Edgbaston, Birmingham.
1891. *James, Charles Henry. 8 Courtland-terrace, Merthyr Tydfil.
1891. *James, Charles Russell. Courtland House, Merthyr Tydfil.
1872. ‡James, Christopher. 8 Laurence Pountney-hill, London, E.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1886. ‡James, Frank. Portland House, Aldridge, near Walsall.
1886. *James, Harry Berkeley, F.R.G.S. 16 Ashburn-place, London, S.W.
1863. *James, Sir Walter, Bart., F.G.S. 6 Whitehall-gardens, London, S.W.
1858. ‡James, William C. Woodside, Plymouth.
1884. ‡Jameson, W. C. 48 Baker-street, Portman-square, London, W.
1881. ‡Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1887. §Jamieson, G. Auldjo. 3 Drumsheugh-gardens, Edinburgh.
1885. ‡Jamieson, Patrick. Peterhead, N.B.
1885. ‡Jamieson, Thomas. 173 Union-street, Aberdeen.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1889. *Japp, F. R., M.A., LL.D., F.R.S., Professor of Chemistry in the University of Aberdeen.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
1870. ‡Jarrold, John James. London-street, Norwich.
1886. §Jeffcock, Rev. John Thomas. The Rectory, Wolverhampton.
1856. §Jeffery, Henry M., M.A., F.R.S. 9 Dunstanville-terrace, Falmouth.
1855. *Jeffray, John. Winton House, Kelvinside, Glasgow.
1883. ‡*Jeffreys, Miss Gwyn. 1 The Terrace, Kensington, London, W.*
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. Pump-court, Temple, London, E.C.
1885. §Jeffreys, Dr. Richard Parker. Eastwood House, Chesterfield.
1887. §Jeffs, Osmund W. 12 Queen's-road, Rock Ferry, Cheshire.
1881. ‡Jellicoe, C. W. A. Southampton.
1864. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.
1873. §Jenkins, Major-General J. J. 16 St. James's-square, London, S.W.
1880. *Jenkins, Sir John Jones. The Grange, Swansea.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1872. ‡Jennings, W. 13 Victoria-street, London, S.W.
1878. ‡Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.
Jessop, William, jun. Overton Hall, Ashover, Chesterfield.
1889. ‡Jevons, F. B., M.A. The Castle, Durham.
1884. ‡Jewell, Lieutenant Theo. F. Torpedo Station, Newport, Rhode Island, U.S.A.
1884. ‡Johns, Thomas W. Yarmouth, Nova Scotia, Canada.
1884. §Johnson, Alexander, M.A., LL.D., Professor of Mathematics in McGill University, Montreal. 5 Prince of Wales-terrace, Montreal, Canada.
1883. ‡Johnson, Miss Alice. Llandaff House, Cambridge.
1883. ‡Johnson, Ben. Micklegate, York.
1871. *Johnson, David, F.C.S., F.G.S. West View, 19 Beulah-hill, Upper Norwood, London, S.E.
1881. ‡Johnson, Colonel E. Cecil. United Service Club, Pall Mall, London, S.W.
1883. ‡Johnson, Edmund Litler. 73 Albert-road, Southport.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1888. §Johnson, J. G. Southwood Court, Highgate, London, N.
1875. ‡Johnson, James Henry, F.G.S. 73 Albert-road, Southport.
1872. ‡Johnson, J. T. 27 Dale-street, Manchester.
1870. ‡Johnson, Richard C., F.R.A.S. 46 Jermyn-street, Liverpool.

Year of Election.

1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1881. ‡Johnson, Samuel George. Municipal Offices, Nottingham.
1890. *Johnson, Thomas, B.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1887. ‡Johnson, W. H. Woodleigh, Altrincham, Cheshire.
1883. ‡Johnson, W. H. F. Llandaff House, Cambridge.
1883. ‡Johnson, William. Harewood, Roe-lane, Southport.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham, Cheshire.
1883. ‡Johnston, H. H. Tudor House, Champion Hill, London, S.E.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston. James. Manor House, Northend, Hampstead, London, N.W.
1884. ‡Johnston, John L. 27 St. Peter-street, Montreal, Canada.
1888. ‡Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.
1884. ‡Johnston, Walter R. Fort Qu'Appelle, N.W. Territory, Canada.
1884. *Johnston, W. H. 6 Latham-street, Preston, Lancashire.
1885. ‡Johnston-Lavis, H. J., M.D., F.G.S. Palazzo Caramanico, Chiatomone, Naples.
1886. ‡Johnstone, G. H. Northampton-street, Birmingham.
1864. *Johnstone, James. Alva House, Alva, by Stirling, N.B.
1876. ‡Johnstone, William. 5 Woodside-terrace, Glasgow.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. ‡Jolly, William, F.R.S.E., F.G.S., H.M. Inspector of Schools. St. Andrew's-road, Pollokshields, Glasgow.
1888. ‡Jolly, W. C. Home Lea, Lansdowne, Bath.
1888. ‡Joly, John. 39 Waterloo-road, Dublin.
1881. ‡Jones, Alfred Orlando, M.D. Cardigan Villa, Harrogate.
1849. ‡Jones, Baynham. Walmer House, Cheltenham.
1887. ‡Jones, D. E., B.Sc. University College, Aberystwith.
1890. §Jones, Rev. Edward. Rockville, Embsay, near Skipton.
1887. ‡Jones, Francis. Beaufort House, Alexandra Park, Manchester.
1883. *Jones, George Oliver, M.A. 5 Cook-street, Liverpool.
1884. ‡Jones, Rev. Harry, M.A. 8 York-gate, Regent's Park, London, N.W.
1877. ‡Jones, Henry C., F.C.S. Normal School of Science, South Kensington, London, S.W.
1881. *Jones, J. Viriamu, M.A., B.Sc., Principal of the University College of South Wales and Monmouthshire. Cardiff.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, London, E.C.
1880. ‡Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡Jones, Thomas Rupert, F.R.S., F.G.S. 10 Uverdale-road, King's-road, Chelsea, London, S.W.
1883. ‡Jones, William. Elsinore, Birkdale, Southport.
1875. *Jose, J. E. 11 Cressington Park, Liverpool.
1884. ‡Joseph, J. H. 738 Dorchester-street, Montreal, Canada.
1875. *Joule, Benjamin St. John B., J.P. Rothesay, N.B.
1847. ‡Jowett, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.
1879. ‡Jowitt, A. Hawthorn Lodge, Clarkehouse-road Sheffield.
1890. §Jowitt, Benson R. Elmhurst, Newton-road, Leeds.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, London, S.W.
1848. *Joy, Rev. Charles Ashfield. West Hanney, Wantage, Berkshire.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, The Hon. Mrs. St. John's Croft, Winchester.
1848. *Jubb, Abraham. Halifax.

Year of Election.

1870. ‡JUDD, JOHN WESLEY, F.R.S., F.G.S., Professor of Geology in the Royal College of Science, London. 31 Ennerdale-road, Kew.

1883. ‡Justice, Philip M. 14 Southampton-buildings, Chancery-lane, London, W.C.

1868. *Kaines, Joseph, M.A., D.Sc. 8 Osborne-road, Stroud Green-road, London, N.

1888. §Kapp, Gisbert. Erba, Wimbledon Park, Surrey.

1887. ‡Kay, Miss. Hamerlaund, Broughton Park, Manchester.

1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, London, W.

Kay, John Cunliff. Fairfield Hall, near Skipton.

1883. ‡Kearne, John H. Westcliffe-road, Birkdale, Southport.

1884. ‡Keefer, Samuel. Brockville, Ontario, Canada.

1884. §Keefer, Thomas Alexander. Port Arthur, Ontario, Canada.

1875. ‡Keeling, George William. Tuthill, Lydney.

1886. ‡Keen, Arthur, J.P. Sandyford, Augustus-road, Birmingham.

1878. **Kelland, William Henry. Grettans, Bow, North Devon.*

1887. ‡Kellas-Johnstone, J. F. 35 Crescent, Salford.

1884. ‡Kellogg, J. H., M D. Battle Creek, Michigan, U.S.A.

1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.

1885. §Keltie, J. Scott, Librarian R.G.S. 1 Savile-row, London, W.

1887. §Kemp, Harry. 254 Stretford-road, Manchester.

1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.

1890. §Kempson, Augustus. Bank House, Northampton.

1875. ‡KENNEDY, ALEXANDER B. W., F.R.S., M.Inst.C.E., Emeritus Professor of Engineering in University College, London. Lawn House, Hampstead-square, London, N.W.

1884. ‡Kennedy, George L., M.A., F.G.S., Professor of Chemistry and Geology in King's College, Windsor, Nova Scotia, Canada.

1876. ‡Kennedy, Hugh. Redclyffe, Partickhill, Glasgow.

1884. ‡Kennedy, John. 113 University-street, Montreal, Canada.

1884. ‡Kennedy, William. Hamilton, Ontario, Canada.

1886. ‡Kenrick, George Hamilton. Whetstone, Somerset-road, Edgbaston, Birmingham.

Kent, J. C. Levant Lodge, Earl's Croome, Worcester.

1886. §Kenward, James, F.S.A. 280 Hagley-road, Birmingham.

1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.

1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.

1881. ‡Kermode, Philip M. C. Ramsay, Isle of Man.

1884. ‡Kerr, James, M.D. Winnipeg, Canada.

1887. ‡Kerr, James. Dunkenhalgh, Accrington.

1883. ‡*Kerr, Dr. John. Garscadden House, near Kilpatrick, Glasgow.*

1889. ‡Kerry, W. H. R. Manor House, Liscard, Cheshire.

1887. ‡Kershaw, James. Holly House, Bury New-road, Manchester.

1869. *Kesselmeyer, Charles A. Villa 'Mon Repos,' Altrincham, Cheshire.

1869. *Kesselmeyer, William Johannes. Villa 'Mon Repos,' Altrincham, Cheshire.

1883. *Keynes, J. N., M.A., B.Sc., F.S.S. 6 Harvey-road, Cambridge.

1876. ‡Kidston, J. B. 50 West Regent-street, Glasgow.

1886. §KIDSTON, ROBERT, F.R.S.E., F.G.S. 24 Victoria-place, Stirling.

1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.

1890. §Kimmins, C. W., M.A., D.Sc. Downing College, Cambridge.

1865. *Kinahan, Sir Edward Hudson, Bart., M.R.I.A. 11 Merrion-square North, Dublin.

Year of Election.

1878. ‡Kinahan, Edward Hudson, jun. 11 Merrion-square North, Dublin.
1860. ‡KINAHAN, G. HENRY, M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1875. *KINCH, EDWARD, F.C.S. Royal Agricultural College, Cirencester.
1888. ‡King, Austin J. Winsley Hill, Limpley Stoke, Bath.
1888. *King, E. Powell. Wainsford, Lymington, Hants.
1883. *King, Francis. Alabama, Penrith.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1883. *King, John Godwin. Wainsford, Lymington, Hants.
1870. ‡King, John Thomson. 4 Clayton-square, Liverpool.
King, Joseph. Welford House, Greenhill, Hampstead, London, N.W.
1883. *King, Joseph, jun. 44 Well-walk, Hampstead, London, N.W.
1860. *King, Mervyn Kersteman. 1 Vittoria-square, Clifton, Bristol.
1875. *King, Percy L. Avonside, Clifton, Bristol.
1888. ‡King, Richard. Grosvenor Lodge, Bath.
1870. ‡King, William. 5 Beach Lawn, Waterloo, Liverpool.
1889. §King, Sir William. Lynwood, Waverley-road, Southsea.
1869. ‡Kingdon, K. Taddiford, Exeter.
1876. §Kingston, Thomas. The Limes, Clewer, near Windsor.
1875. §KINGZETT, CHARLES T., F.C.S. Trevena, Amhurst Park, London, N.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1860. ‡KIRKMAN, Rev. THOMAS P., M.A., F.R.S. Croft Rectory, near Warrington.
1875. ‡Kirsop, John. 6 Queen's-crescent, Glasgow.
1883. ‡Kirsop, Mrs. 6 Queen's-crescent, Glasgow.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1890. *KITSON, Sir JAMES, Bart. Gledhow Hall, Leeds.
1886. ‡Klein, Rev. L. Martial. University College, Dublin.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1886. §Knight, J. M. Bushwood, Wanstead, Essex.
1883. ‡Knight, J. R. 32 Lincoln's Inn-fields, London, W.C.
1888. ‡Knott, Cargill G., D.Sc., F.R.S.E. Tokio, Japan.
1872. *Knott, George, LL.B., F.R.A.S. Knowles Lodge, Cuckfield, Hayward's Heath, Sussex.
1887. *Knott, Herbert. Wharf Street Mills, Ashton-under-Lyne.
1887. *Knott, John F. Staveleigh, Stalybridge, Cheshire.
1887. ‡Knott, Mrs. Staveleigh, Stalybridge, Cheshire.
1887. §Knott, T. B. Ellerslie, Cheadle Hulme, Cheshire.
1873. *Knowles, George. Moorhead, Shipley, Yorkshire.
1872. ‡*Knowles, James. The Hollies, Clapham Common, S.W.*
1870. ‡*Knowles, Rev. J. L.* 103 *Earl's Court-road, Kensington, London, W.*
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1883. ‡Knowlys, Rev. C. Hesketh. The Rectory, Roe-lane, Southport.
1883. ‡Knowlys, Mrs. C. Hesketh. The Rectory, Roe-lane, Southport.
1876. ‡Knox, David N., M.A., M.B. 24 Elmbank-crescent, Glasgow.
*Knox, George James. 29 Portland-terrace, Regent's Park, London, N.W.
1875. *Knubley, Rev. E. P., M.A. Staveley Rectory, Leeds.
1883. ‡Knubley, Mrs. Staveley Rectory, Leeds.
1890. *Krauss, John Samuel. Whitecot, Wilmslow, Cheshire.
1888. *Kunz, G. F. Care of Messrs. Tiffany & Co., Union-square, New York City, U.S.A.
1881. ‡Kurobe, Hiroo. Legation of Japan, 9 Cavendish-square, London, W.

Year of Election.

1870. ‡Kynaston, Josiah W., F.C.S. Kensington, Liverpool.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.

1858. ‡Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1884. ‡Laflamme, Rev. Professor J. C. K. Laval University, Quebec, Canada.
1885. *Laing, J. Gerard. 1 Elm-court, Temple, London, E.C.
1870. ‡Laird, H. H. Birkenhead.
1870. §Laird, John. Grosvenor-road, Claughton, Birkenhead.
1882. ‡Lake, G. A. K., M.D. East Park-terrace, Southampton.
1877. ‡Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1889. *Lamb, Edmund., M.A. Union Club, Trafalgar-square, London, S.W.
1887. ‡Lamb, Horace, M.A., F.R.S., Professor of Pure Mathematics in the Owens College, Manchester. Burton-road, Didsbury, Manchester.
1887. ‡Lamb, James. Kenwood, Bowdon, Cheshire.
1883. ‡Lamb, W. J. 11 Gloucester-road, Birkdale, Southport.
1883. ‡LAMBERT, Rev. BROOKE, LL.B. The Vicarage, Greenwich, Kent, S.E.
1884. ‡Lamborn, Robert H. Montreal, Canada.
1890. §Lamport, Edward Parke. Greenfield Well, Lancaster.
1884. ‡Lancaster, Alfred. Fern Bank, Burnley, Lancashire.
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1886. ‡Lancaster, W. J., F.G.S. Colmore-row, Birmingham.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 59 Tresillian-road, St. John's, S.E.
1883. ‡Lang, Rev. Gavin. Inverness.
1859. ‡Lang, Rev. John Marshall, D.D. Barony, Glasgow.
1886. *LANGLEY, J. N., M.A., F.R.S. Trinity College, Cambridge.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
1865. ‡LANKESTER, E. RAY, M.A., LL.D., F.R.S., Linacre Professor of Human and Comparative Anatomy in the University of Oxford. 42 Half Moon-street, Piccadilly, London, W.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Care of Mr. Wheldon, 58 Great Queen-street, Lincoln's Inn-fields, London, W.C.
1884. ‡Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1886. ‡*Lapraik, W. 9 Malfort-road, Denmark Hill, London, S.E.*
1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S., Professor of Geology and Mineralogy in the Mason Science College, Birmingham. 13 Duchess-road, Edgbaston, Birmingham.
1887. ‡Larmor, Alexander. Clare College, Cambridge.
1881. ‡Larmor, Joseph, M.A. St. John's College, Cambridge.
1883. §Lascelles, B. P. Harrow.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1870. ‡LAUGHTON, JOHN KNOX, M.A., F.R.G.S. 130 Sinclair-road, West Kensington Park, London, W.
1888. ‡LAURIE, Colonel R. P., C.B., M.P. 35 Eaton-place, London, S.W.
1883. ‡Laurie, Major-General. Oakfield, Nova Scotia.
1870. *Law, Channell. Ilsham Dene, Torquay.
1878. ‡Law, Henry, M.Inst.C.E. 9 Victoria-chambers, London, S.W.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
1884. §Law, Robert. 11 Cromwell-terrace, West Hill Park, Halifax, Yorkshire.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.

Year of Election.

1881. ‡Lawrence, Rev. F., B.A. The Vicarage, Westow, York.
1889. §Laws, W. G. 5 Winchester-terrace, Newcastle-upon-Tyne.
1875. ‡Lawson, George, Ph.D., LL.D., Professor of Chemistry and Botany. Halifax, Nova Scotia.
1885. ‡Lawson, James. 8 Church-street, Huntly, N.B.
1868. *Lawson, M. Alexander, M.A., F.L.S. Ootâcamund, Bombay.
1853. ‡Lawton, William. 5 Victoria-terrace, Derringham, Hull.
1888. §Layard, Miss Nina F. 11 Museum-street, Ipswich.
1856. ‡Lea, Henry. 38 Bennett's-hill, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1883. §Leach, John. Haverhill House, Bolton.
1875. ‡Leach, Colonel R. E. Mountjoy, Phœnix Park, Dublin.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. 6 Sussex-place, Regent's Park, London, N.W.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1884. ‡Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.
1847. *Leatham, Edward Aldam, M.P. Whitley Hall, Huddersfield; and 46 Eaton-square, London, S.W.
1863. ‡Leavers, J. W. The Park, Nottingham.
1884. *Leavitt, Erasmus Darwin. 604 Main-street, Cambridgeport, Massachusetts, U.S.A.
1872. ‡Lebour, G. A., M.A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne.
1884. ‡Leckie, R. G. Springhill, Cumberland County, Nova Scotia.
1883. ‡Lee, Daniel W. Halton Bank, Pendleton, near Manchester.
1861. ‡Lee, Henry, M.P. Sedgeley Park, Manchester.
1883. ‡*Lee, J. H. Warburton. Rossall, Fleetwood.*
1887. *Lee, Sir Joseph Cooksey. Park Gate, Altrincham.
1884. *Leech, Bosdin T. Oak Mount, Timperley, Cheshire.
1887. ‡Leech, D. J., M.D., Professor of Materia Medica in the Owens College, Manchester. Elm House, Whalley Range, Manchester.
1886. *Lees, Lawrence W. Claregate, Tettenhall, Wolverhampton.
1882. ‡Lees, R. W. Moira-place, Southampton.
1859. ‡Lees, William, M.A. St. Leonard's, Morningside-place, Edinburgh.
1883. *Leese, Miss H. K. Fylde-road Mills, Preston, Lancashire.
*Leese, Joseph. Fylde-road Mills, Preston, Lancashire.
1883. ‡Leese, Mrs. Hazeldene, Fallowfield, Manchester.
1889. *Leeson, John Rudd, M.D., F.G.S. Clifden House, Twickenham, Middlesex.
1881. ‡Le Feuvre, J. E. Southampton.
1872. ‡Lefevre, The Right Hon. G. Shaw, M.P., F.R.G.S. 18 Bryanston square, London, W.
*Legh, Lieut.-Colonel George Cornwall. High Legh Hall, Cheshire.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1868. ‡Leicester, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1856. ‡Leigh, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.
1890. §Leigh, Marshall. 22 Goldsmid-row, Brighton.
1886. §Leipner, Adolph, Professor of Botany in University College, Bristol. 47 Hampton Park, Bristol.
1867. ‡Leishman, James. Gateacre Hall, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. ‡Lemon, James, M.Inst.C.E. 11 The Avenue, Southampton.
1867. ‡Leng, John. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.

Year of
Election.

1887. *Leon, John T. 38 Portland-place, London, W.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1884. ‡Lesage, Louis. City Hall, Montreal, Canada.
1871. ‡Leslie, Alexander, M.Inst.C.E. 72 George-street, Edinburgh.
1890. *Lester, Joseph Henry. Fir Bank, Penrith.
1883. §Lester, Thomas. Fir Bank, Penrith.
1880. ‡LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1887. ‡Leverkus, Otto. The Downs, Prestwich, Manchester.
1887. **Levinstein, Ivan. Villa Newberg, Victoria Park, Manchester.*
1890. §Levy, J. H. Florence, 12 Abbeville-road South, Clapham Park, London, S.W.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, London, S.W.
1870. ‡LEWIS, ALFRED LIONEL. 54 Highbury-hill, London, N.
1884. *Lewis, Sir W. T. The Mardy, Aberdare.
1853. ‡Liddell, George William Moore. Sutton House, near Hull.
1860. ‡LIDDELL, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1887. ‡Liebermann, L. 54 Portland-street, Manchester.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1887. *Lightbown, Henry. Weaste Hall, Pendleton, Manchester.
1862. ‡LILFORD, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*LIMERICK, The Right Rev. CHARLES GRAVES, Lord Bishop of, D.D., F.R.S., M.R.I.A. The Palace, Henry-street, Limerick.
1887. ‡Limpach, Dr. Crumpsall Vale Chemical Works, Manchester.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1881. *Lindley, William, M.Inst.C.E., F.G.S. 74 Shooters Hill-road, Blackheath, London, S.E.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
1876. ‡Linn, James. Geological Survey Office, India-buildings, Edinburgh.
1883. §Lipscomb, Mrs. Lancelot C. d'A. 95 Elgin-crescent, London, W.
1883. ‡Lisle, H. Claud. Nantwich.
1882. *Lister, Rev. Henry, M.A. Hawridge Rectory, Berkhampstead.
1888. ‡Lister, J. J. Leytonstone, Essex, E.
1876. ‡Little, Thomas Evelyn. 42 Brunswick-street, Dublin.
1881. ‡*Littlewood, Rev. B. C., M.A. Holmdale, Cheltenham.*
1861. *LIVEING, G. D., M.A., F.R.S., F.C.S., Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1876. *Liversidge, Archibald, F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry and Mineralogy in the University of Sydney, N.S.W. Care of Messrs. Trübner & Co., Ludgate Hill, London, E.C.
1864. §Livesay, J. G. Cromartie House, Ventnor, Isle of Wight.
1880. ‡LLEWELYN, Sir JOHN T. D., Bart. Penllegare, Swansea.
Lloyd, Rev. A. R. Hengold, near Oswestry.
1889. ‡Lloyd, Rev. Canon. The Vicarage, Rye Hill, Newcastle-upon-Tyne.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B., J.P. Edgbaston-grove, Birmingham.
1865. ‡Lloyd, John. Queen's College, Birmingham.
1886. ‡Lloyd, John Henry. Ferndale, Carpenter-road, Edgbaston, Birmingham.
1886. ‡Lloyd, Samuel. Farm, Sparkbrook, Birmingham.
1865. *Lloyd, Wilson, F.R.G.S. Myvod House, Wednesbury.
1854. *LOBLEY, JAMES LOGAN, F.G.S., F.R.G.S. City of London College, Moorgate-street, London, E.C.

Year of Election.

1867. *Locke, John. Whitehall Club, London, S.W.
1863. ‡LOCKYER, J. NORMAN, F.R.S., F.R.A.S. Royal College of Science, South Kensington, London, S.W.
1886. *Lodge, Alfred, M.A., Professor of Pure Mathematics in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1875. *LODGE, OLIVER J., D.Sc., LL.D., F.R.S., Professor of Physics in University College, Liverpool. 21 Waverley-road, Sefton Park, Liverpool.
1889. ‡Logan, William. Langley Park, Durham.
1876. ‡Long, H. A. Charlotte-street, Glasgow.
1871. *Long, John Jex. 11 Doune-terrace, Kelvinside, Glasgow.
1851. ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1883. *Long, William. Thelwall Heys, near Warrington.
1883. ‡Long, Mrs. Thelwall Heys, near Warrington.
1883. ‡Long, Miss. Thelwall Heys, near Warrington.
1866. ‡Longdon, Frederick. Osmaston-road, Derby.
1883. ‡Longe, Francis D. Coddenham Lodge, Cheltenham.
1883. ‡Longmaid, William Henry. 4 Rawlinson-road, Southport.
1875. *Longstaff, George Blundell, M.A., M.B., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1871. §Longstaff, George Dixon, M.D., F.C.S. Butterknowle, Wandsworth, S.W.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, Surrey.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, Surrey.
1883. *Longton, E. J., M.D. Lord-street, Southport.
1861. *Lord, Edward. Adamroyd, Todmorden.
1889. ‡Lord, Riley. Highfield House, Gosforth, Newcastle-upon-Tyne.
1863. ‡Losh, W. S. Wreay Syke, Carlisle.
1883. *Louis, D. A., F.C.S. 77 Shirland-gardens, London, W.
1887. *Love, A. E. H. St. John's College, Cambridge.
1886. *Love, E. F. J., M.A. The University, Melbourne, Australia.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 11 Notting Hill-square, London, W.
1883. §Love, James Allen. 8 Eastbourne-road West, Southport.
1875. *Lovett, W. Jesse, F.I.C. 154 Eccles New-road, Salford.
1889. ‡Low, Charles W. 84 Westbourne-terrace, London, W.
1867. *Low, James F. Monifieth, by Dundee.
1885. §Lowdell, Sydney Poole. Baldwyn's Hill, East Grinstead, Sussex.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1861. *LOWE, EDWARD JOSEPH, F.R.S., F.R.A.S., F.L.S., F.G.S., F.R.M.S. Shirenewton Hall, near Chepstow.
1884. ‡Lowe, F. J. Elm-court, Temple, London, E.C.
1886. *Lowe, John Landor, M.Inst.C.E. Engineer's Office, Midland Railway, Derby.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1881. ‡Lubbock, Arthur Rolfe. High Elms, Hayes, Kent.
1853. *LUBBOCK, The Right Hon. Sir JOHN, Bart., M.P., D.C.L., LL.D., F.R.S., F.L.S., F.G.S. Down, Farnborough, Kent.
1881. ‡Lubbock, John B. High Elms, Hayes, Kent.
1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, London, W.
1889. ‡Lucas, John. 1 Carlton-terrace, Low Fell, Gateshead.
1878. ‡Lucas, Joseph. Tooting Graveney, London, S.W.
1889. ‡Luckley, George. 7 Victoria-square, Newcastle-upon-Tyne.
1875. ‡Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.

Year of Election.

1873. ‡Lumley, J. Hope Villa, Thornbury, near Bradford, Yorkshire.
1885. ‡*Lumsden, Robert. Ferryhill House, Aberdeen.*
1866. *Lund, Charles. Ilkley, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 321 Newport-road, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S., Professor of Mining Engineering in Yorkshire College. 6 De Grey-road, Leeds.
1874. *LUPTON, SYDNEY, M.A. Grove Cottage, Roundhay, near Leeds.
1864. *Lutley, John. Brockhampton Park, Worcester.
1871. ‡Lyell, Leonard, F.G.S. 92 Onslow-gardens, London, S.W.
1884. ‡Lyman, A. Clarence. 84 Victoria-street, Montreal, Canada.
1884. ‡Lyman, H. H. 74 McTavish-street, Montreal, Canada.
1884. ‡Lyman, Roswell C. 74 McTavish-street, Montreal, Canada.
1874. ‡Lynam, James. Ballinasloe, Ireland.
1885. §Lyon, Alexander, jun. 52 Carden-place, Aberdeen.
1857. ‡*Lyons, Robert D., M.B., M.R.I.A. 8 Merrion-square West, Dublin.*
1878. ‡*Lyte, Cecil Maxwell. Cotford, Oakhill-road, Putney, S.W.*
1862. *LYTE, F. MAXWELL, F.C.S. 60 Finborough-road, London, S.W.

1852. ‡McAdam, Robert. 18 College-square East, Belfast.
1854. *MACADAM, STEVENSON, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1876. *MACADAM, WILLIAM IVISON. Surgeons' Hall, Edinburgh.
1868. ‡MACALISTER, ALEXANDER, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. ‡MACALISTER, DONALD, M.A., M.D., B.Sc. St. John's College, Cambridge.
1879. §MacAndrew, James J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, William. Westwood House, near Colchester.
1866. *M'Arthur, Alexander, M.P., F.R.G.S. 79 Holland Park, London, W.
1884. ‡Macarthur, Alexander. Winnipeg, Canada.
1884. ‡Macarthur, D. Winnipeg, Canada.
1834. MACAULAY, JAMES, A.M., M.D. 25 Carlton-road, Maida Vale, London, N.W.
1840. *MacBrayne, Robert. 65 West Regent-street, Glasgow.
1884. ‡McCabe, T., Chief Examiner of Patents. Patent Office, Ottawa, Canada.
1855. ‡*M'Cann, Rev. James, D.D., F.G.S. The Lawn, Lower Norwood, Surrey, S.E.*
1886. ‡MacCarthy, Rev. E. F. M., M.A. 93 Hagley-road, Birmingham.
1887. *McCarthy, James. Bangkok, Siam.
1884. *McCarthy, J. J., M.D. 83 Wellington-road, Dublin.
1884. ‡McCausland, Orr. Belfast.
1876. *M'CLELLAND, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1868. ‡M'CLINTOCK, Admiral Sir FRANCIS L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. **M'Clure, J. H., F.R.G.S. Chavoire Annecy, Haute Savoie, France.*
1874. ‡M'Clure, Sir Thomas, Bart. Belmont, Belfast.
1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.
1858. ‡M'Connell, J. E. Woodlands, Great Missenden.
1883. ‡McCrossan, James. 92 Huskisson-street, Liverpool.
1876. ‡*M'Culloch, Richard. 109 Douglas-street, Blythswood-square, Glasgow.*

Year of Election.

1884. ‡MACDONALD, The Right Hon. Sir JOHN ALEXANDER, G.C.B., D.C.L., LL.D. Ottawa, Canada.
1886. ‡McDonald, John Allen. Hillsboro' House, Derby.
1884. ‡MacDonald, Kenneth. Town Hall, Inverness.
1884. *McDonald, W. C. 891 Sherbrooke-street, Montreal, Canada.
1878. ‡McDonnell, Alexander. St. John's, Island Bridge, Dublin.
1884. ‡MacDonnell, Mrs. F. H. 1433 St. Catherine-street, Montreal, Canada.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1883. ‡MacDonnell, Rev. Canon J. C., D.D. Misterton Rectory, Lutterworth.
1878. ‡McDonnell, James. 32 Upper Fitzwilliam-street, Dublin.
1884. ‡Macdougall, Alan. Toronto, Canada.
1884. ‡McDougall, John. 35 St. François Xavier-street, Montreal, Canada.
1881. ‡Macfarlane, Alexander, D.Sc., F.R.S.E., Professor of Physics in the University of Texas. Austin, Texas, U.S.A.
1871. ‡M'Farlane, Donald. The College Laboratory, Glasgow.
1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E. 15 Scotland-street, Edinburgh.
1879. ‡Macfarlane, Walter, jun. 12 Lynedoch-crescent, Glasgow.
1884. ‡Macfie, K. N., B.A., B.C.L. Winnipeg, Canada.
1854. *Macfie, Robert Andrew. Dreghorn, Colinton, Edinburgh.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1855. ‡*MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.*
1888. §MacGeorge, James. 67 Marloes-road, Kensington, London, W.
1884. ‡MacGillivray, James. 42 Cathcart-street, Montreal, Canada.
1884. ‡MacGoun, Archibald, jun., B.A., B.C.L. 19 Place d'Armes, Montreal, Canada.
1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.
1885. ‡Macgregor, Alexander, M.D. 256 Union-street, Aberdeen.
1884. *MACGREGOR, JAMES GORDON, M.A., D.Sc., F.R.S.E., Professor of Physics in Dalhousie College, Halifax, Nova Scotia, Canada.
1886. ‡McGregor, William. Kohima Lodge, Bedford.
1885. ‡M'Gregor-Robertson, J., M.A., M.B. 400 Great Western-road, Glasgow.
1876. ‡M'Grigor, Alexander B., LL.D. 19 Woodside-terrace, Glasgow.
1867. *M'INTOSH, W. C., M.D., LL.D., F.R.S. L. & E., F.L.S., Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1884. ‡McIntyre, John, M.D. Odiham, Hants.
1883. ‡Mack, Isaac A. Trinity-road, Bootle.
1884. ‡Mackay, Alexander Howard, B.A., B.Sc. The Academy, Pictou, Nova Scotia, Canada.
1885. §MACKAY, JOHN YULE, M.D. The University, Glasgow.
1873. ‡MCKENDRICK, JOHN G., M.D., F.R.S. L. & E., Professor of Physiology in the University of Glasgow. The University, Glasgow.
1883. ‡McKendrick, Mrs. The University, Glasgow.
1880. *Mackenzie, Colin. Junior Athenæum Club, Piccadilly, London, W.
1884. ‡McKenzie, Stephen, M.D. 26 Finsbury-circus, London, E.C.
1884. ‡McKenzie, Thomas, B.A. School of Science, Toronto, Canada.
1883. ‡Mackeson, Henry. Hythe, Kent.
1865. ‡Mackeson, Henry B., F.G.S. Hythe, Kent.
1872. *Mackey, J. A. 1 Westbourne-terrace, Hyde Park, London, W.
1867. ‡MACKIE, SAMUEL JOSEPH. 17 Howley-place, London, W.
1884. ‡McKilligan, John B. 387 Main-street, Winnipeg, Canada.
1887. §Mackinder, H. J., M.A., F.R.G.S. Christ Church, Oxford.
1867. *Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.

Year of Election.

1889. §McKinley, Rev. D. 33 Milton-street, West Hartlepool.
1884. *Mackintosh, James B. Consolidated Gas Company, 21st-street, and Avenue A, New York City, U.S.A.
1850. ‡Macknight, Alexander. 20 Albany-street, Edinburgh.
1867. ‡Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *McLachlan, Robert, F.R.S., F.L.S. West View, Clarendon-road, Lewisham, S.E.
1873. ‡McLandsborough, John, M.Inst.C.E., F.R.A.S., F.G.S. Manningham, Bradford, Yorkshire.
1885. *M'Laren, The Right Hon. Lord, F.R.S.E. 46 Moray-place, Edinburgh.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1882. ‡Maclean, Inspector-General, C.B. 1 Rockstone-terrace, Southampton.
1884. ‡McLennan, Frank. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, Hugh. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, John. Lancaster, Ontario, Canada.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Campden Hill-road, London, W.
1868. §M'Leod, Herbert, F.R.S., F.C.S., Professor of Chemistry in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1875. ‡Macliver, D. 1 Broad-street, Bristol.
1875. ‡Macliver, P. S. 1 Broad-street, Bristol.
1861. *Maclure, John William, M.P., F.R.G.S., F.S.S. Whalley Range, Manchester.
1883. *McMahon, Major-General C. A. 20 Nevern-square, South Kensington, London, S.W.
1883. ‡MacMahon, Captain P. A., R.A., F.R.S., Instructor in Mathematics at the Royal Military Academy, Woolwich.
1878. *M'Master, George, M.A., J.P. Donnybrook, Ireland.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey, S.W.
1888. §McMillan, Robert. 20 Aubrey-street, Liverpool.
1874. ‡MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1867. ‡M'Neill, John. Balhousie House, Perth.
1883. ‡McNicoll, Dr. E. D. 15 Manchester-road, Southport.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1887. ‡Maconochie, Archibald White. Care of Messrs. Maconochie Bros., Lowestoft.
1883. ‡Macpherson, J. 44 Frederick-street, Edinburgh.
1886. ‡Macpherson, Lieut.-Colonel J. C., R.E. Ordnance Survey Office, Southampton.
1887. §McRae, Charles, M.A. Science and Art Department, South Kensington, London, S.W.
*Macrory, Edmund, M.A. 2 Ilchester-gardens, Prince's-square, London, W.
1883. ‡McWhirter, William. 170 Kent-road, Glasgow.
1887. ‡Macy, Jesse. Grinnell, Iowa, U.S.A.
1883. ‡Madden, W. H. Marlborough College, Wilts.
1883. ‡*Maggs, Thomas Charles, F.G.S. Culver Lodge, Acton Vale, Middlesex, W.*
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Sir Philip, B.Sc. 48 Gloucester-place, Portman-square, London, W.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1869. ‡Main, Robert. The Admiralty, Whitehall, London, S.W.
1887. ‡Mainprice, W. S. Longcroft, Altrincham, Cheshire.
1885. *Maitland, Sir James R. G., Bart. Stirling, N.B.

Year of Election.

1883. §Maitland, P. C. 136 Great Portland-street, London, W.
*Malcolm, Frederick. Morden College, Blackheath, London, S.E.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1889. ‡Maling, C. T. 14 Ellison-place, Newcastle-upon-Tyne.
1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.
1887. ‡Manchester, The Right Rev. the Lord Bishop of, D.D. Bishop's Court, Manchester.
1870. ‡Manifold, W. H., M.D. 45 Rodney-street, Liverpool.
1885. ‡Mann, George. 72 Bon Accord-street, Aberdeen.
1888. ‡Mann, W. J. Rodney House, Trowbridge.
Manning, His Eminence Cardinal. Archbishop's House, Westminster, S.W.
1878. §Manning, Robert. 4 Upper Ely-place, Dublin.
1864. ‡Mansel-Pleydell, J. C. Whatcombe, Blandford.
1888. ‡Mansergh, James, M.Inst.C.E. 3 Westminster-chambers, London, S.W.
1889. ‡Manville, E. 3 Prince's-mansions, Victoria-street, London, S.W.
1887. *March, Henry Colley, M.D. 2 West-street, Rochdale.
1870. ‡Marcoartu, His Excellency Don Arturo de. Madrid.
1887. ‡Margetson, J. Charles. The Rocks, Limpley, Stoke.
1883. ‡Marginson, James Fleetwood. The Mount, Fleetwood, Lancashire.
1887. §Markham, Christopher A., F.R.Met.Soc. Sedgebrook, Northampton.
1864. ‡Markham, Clements R., C.B., F.R.S., F.L.S., F.R.G.S., F.S.A. 21 Eccleston-square, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
1888. ‡Marling, W. J. Stanley Park, Stroud, Gloucestershire.
1888. ‡Marling, Lady. Stanley Park, Stroud, Gloucestershire.
1881. *Marr, John Edward, M.A., F.G.S. St. John's College, Cambridge.
1888. §Marriott, A. S. Manor Lawn, Dewsbury.
1857. ‡Marriott, William, F.C.S. 8 Belgrave-terrace, Huddersfield.
1887. ‡Marsden, Benjamin. Westleigh, Heaton Mersey, Manchester.
1887. ‡Marsden, Joseph. Ardenlea, Heaton, near Bolton.
1884. *Marsden, Samuel. St. Louis, Missouri, U.S.A.
1883. *Marsh, Henry. Cressy House, Woodsley-road, Leeds.
1887. §Marsh, J. E., B.A. The Museum, Oxford.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1889. *Marshall, Alfred, M.A., Professor of Political Economy in the University of Cambridge. Balliol Croft, Madingley-road, Cambridge.
1882. *Marshall, A. Milnes, M.A., M.D., D.Sc., F.R.S., Professor of Zoology in Owens College, Manchester.
1889. ‡Marshall, Frank, B.A. 31 Grosvenor-place, Newcastle-upon-Tyne.
1881. *Marshall, John, F.R.A.S., F.G.S. Church Institute, Leeds.
1890. §Marshall, John. Derwent Island, Keswick.
1881. ‡Marshall, John Ingham Fearby. 28 St. Saviourgate, York.
1876. ‡Marshall, Peter. 6 Parkgrove-terrace, Glasgow.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
1889. *Marshall, Miss Sophie Elise, B.Sc. 38 Percy-gardens, Tynemouth.
1887. §Marshall, William. Thorncliffe, Dukinfield.
1886. *Marshall, William Bayley, M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1849. *Marshall, William P., M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1865. §Marten, Edward Bindon. Pedmore, near Stourbridge.

Year of Election.

1883. ‡Marten, Henry John. 4 Storey's-gate, London, S.W.
1887. *Martin, Rev. H. A. Laxton Vicarage, Newark.
1891. *Martin, Edward P., J.P. Dowlais, Glamorgan.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1878. ‡Martin, H. Newell, M.A., M.D., D.Sc., F.R.S., Professor of Biology in Johns Hopkins University, Baltimore, U.S.A.
1883. *Martin, John Biddulph, M.A., F.S.S. 17 Hyde Park-gate, London, S.W.
1884. §Martin, N. H., F.L.S. 85 Osborne-road, Jesmond, Newcastle-upon-Tyne.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Lyon House, New Barnet, Herts.
1890. §Martindale, William. 19 Devonshire-street, Portland-place, London, W.
*Martineau, Rev. James, LL.D., D.D. 35 Gordon-square, London, W.C.
1865. ‡Martineau, R. F. 18 Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1886. ‡Martineau, Sir Thomas, J.P. West Hill, Augustus-road, Edgbaston, Birmingham.
1883. ‡Marwick, James, LL.D. Killermont, Maryhill, Glasgow.
1878. ‡Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-street Within, London, E.C.
1847. ‡Maskelyne, Nevil Story, M.A., M.P., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. Salthrop, Wroughton, Wiltshire.
1886. ‡Mason, Hon. J. E. Fiji.
1879. ‡Mason, James, M.D. Montgomery House, Sheffield.
1876. ‡Mason, Robert. 6 Albion-crescent, Dowanhill, Glasgow.
Massey, Lord Hugh. Hermitage, Castleconnel, Co. Limerick.
1885. ‡Masson, Orme, D.Sc. 58 Great King-street, Edinburgh.
1883. ‡Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1887. *Mather, William, M.P., M.Inst.C.E. Salford Iron Works, Manchester.
1890. §Mathers, J. S. 1 Hanover-square, Leeds.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1889. §Mathews, John Hitchcock. 1 Queen's-gardens, Hyde Park, London, W.
1861. *Mathews, William, M.A., F.G.S. 60 Harborne-road, Birmingham.
1881. ‡Mathwin, Henry, B.A. Bickerton House, Southport.
1883. ‡Mathwin, Mrs. 40 York-road, Birkdale, Southport.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1885. ‡Matthews, James. Springhill, Aberdeen.
1885. ‡Matthews, J. Duncan. Springhill, Aberdeen.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.
1890. §Maund, E. A. 294 Regent-street, London, W.
1865. *Maw, George, F.L.S., F.G.S., F.S.A. Kenley, Surrey.
1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.
1864. *Maxwell, Francis. 4 Moray-place, Edinburgh.
1887. ‡Maxwell, James. 29 Princess-street, Manchester.
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1883. §May, William, F.G.S., F.R.G.S. Northfield, St. Mary Cray, Kent.
1883. ‡Mayall, George. Clairville, Birkdale, Southport.
1884. *Maybury, A. C., D.Sc. 19 Bloomsbury-square, London, W.C.
1878. *Mayne, Thomas, M.P. 33 Castle-street, Dublin.

Year of
Election.

1890. §Mays-Robson, A. W., F.R.C.S. Hilary-place, Leeds.
1863. ‡*Mease, George D. Lydney, Gloucestershire.*
1878. ‡Meath, The Right Rev. C. P. Reichel, D.D., Bishop of. Dundrum Castle, Dublin.
1884. ‡Mecham, Arthur. 11 Newton-terrace, Glasgow.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, London, W.
1887. §Meischke-Smith, W. Rivala Lumpore, Salengore, Straits Settlements.
1881. *MELDOLA, RAPHAEL, F.R.S., F.R.A.S., F.C.S., F.I.C., Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, London, W.C.
1867. ‡MELDRUM, CHARLES, C.M.G., LL.D., F.R.S., F.R.A.S. Port Louis, Mauritius.
1883. ‡Mellis, Rev. James. 23 Park-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. Mapperley Vicarage, Derby.
1883. §Mello, Mrs. J. M. Mapperley Vicarage, Derby.
1881. §Melrose, James. Clifton, York.
1887. ‡Melvill, J. Cosmo, M.A. Kersal Cottage, Prestwich, Manchester.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1877. *Menabrea, General Count, LL.D. 14 Rue de l'Elysée, Paris.
1862. §MENNELL, HENRY T. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1879. §MERIVALE, JOHN HERMAN, M.A., Professor of Mining in the College of Science, Newcastle-upon-Tyne.
1879. ‡*Merivale, Walter. Indian Midland Railway, Sangor.*
1877. ‡Merrifield, John, Ph.D., F.R.A.S. Gascoigne-place, Plymouth.
1880. ‡Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. ‡MIALL, LOUIS C., F.L.S., F.G.S., Professor of Biology in Yorkshire College, Leeds.
1886. ‡Middlemore, Thomas. Holloway Head, Birmingham.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of, Middlesbrough.
1883. ‡Middleton, Henry. St. John's College, Cambridge.
1881. ‡Middleton, R. Morton, F.L.S., F.Z.S. South Pittsburg, Tennessee.
1886. *Middleton, Robert T. 197 West George-street, Glasgow.
1889. §Milburn, John D. Queen-street, Newcastle-upon-Tyne.
1886. ‡Miles, Charles Albert. Buenos Ayres.
1881. §MILES, MORRIS. Warbourne, Hill-lane, Southampton.
1885. §Mill, Hugh Robert, D.Sc., F.R.S.E. Braid-road, Morningside, Edinburgh.
1859. ‡Millar, John, J.P. Lisburn, Ireland.
1889. *Millar, Robert Cockburn. 56 George-street, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1876. ‡Millar, William. Highfield House, Dennistoun, Glasgow.
1876. ‡Millar, W. J. 145 Hill-street, Garnethill, Glasgow.
1882. ‡Miller, A. J. 12 Cumberland-place, Southampton.
1875. ‡Miller, George. Brentry, near Bristol.
1884. ‡Miller, Mrs. Hugh. 51 Lauriston-place, Edinburgh.
1888. ‡Miller, J. Bruce. Rubislaw Den North, Aberdeen.
1885. ‡Miller, John. 9 Rubislaw-terrace, Aberdeen.

Year of Election.

1886. §Miller, Rev. John. The College, Weymouth.
1861. *Miller, Robert. Cranage Hall, Holmes Chapel, Cheshire.
1876. *Miller, Robert. 1 Lily Bank-terrace, Hillhead, Glasgow.
1884. ‡Miller, T. F., B.Ap.Sc. Napanee, Ontario, Canada.
1876. ‡Miller, Thomas Paterson. Cairns, Cambuslang, N.B.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in the Glasgow and West of Scotland Technical College, Glasgow. 60 John-street, Glasgow.
1880. ‡Mills, Mansfeldt H. Old Hall, Mansfield Woodhouse, Mansfield.
1885. ‡Milne, Alexander D. 40 Albyn-place, Aberdeen.
1882. *MILNE, JOHN, F.R.S., F.G.S., Professor of Mining and Geology in the Imperial College of Engineering, Tokio, Japan. Ingleside, Birdhirst Rise, South Croydon, Surrey.
1885. ‡Milne, J. D. 14 Rubislaw-terrace, Aberdeen.
1885. ‡Milne, William. 40 Albyn-place, Aberdeen.
1887. ‡Milne-Redhead, R., F.L.S. Holden Clough, Clitheroe.
1882. ‡Milnes, Alfred, M.A., F.S.S. 30 Almeric-road, London, S.W.
1888. ‡Milsom, Charles. 69 Pulteney-street, Bath.
1880. ‡Minchin, G. M., M.A. Royal Indian Engineering College, Cooper's Hill, Surrey.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1876. ‡Mitchell, Andrew. 20 Woodside-place, Glasgow.
1883. ‡Mitchell, Charles T., M.A. 41 Addison-gardens North, Kensington, London, W.
1883. ‡Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, London, W.
1863. ‡Mitchell, C. Walker. Newcastle-upon-Tyne.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1885. ‡Mitchell, Rev. J. Mitford, B.A. 6 Queen's-terrace, Aberdeen.
1870. ‡Mitchell, John, J.P. York House, Clitheroe, Lancashire.
1868. ‡*Mitchell, John, jun. Pole Park House, Dundee.*
1885. ‡Mitchell, P. Chalmers. Christ Church, Oxford.
1862. *Mitchell, W. Stephen, M.A., LL.B. Kenyon Mansions, Loughborough Park, London, S.W.
1879. ‡MIVART, ST. GEORGE, Ph.D., M.D., F.R.S., F.L.S., F.Z.S. Hurstcote, Chilworth, Surrey.
1884. ‡*Moat, Robert. Spring Grove, Bewdley.*
1885. §Moffat, William. 7 Queen's-gardens, Aberdeen.
1864. ‡Mogg, John Rees. High Littleton House, near Bristol.
1885. ‡Moir, James. 25 Carden-place, Aberdeen.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1878. ‡Molloy, Constantine, Q.C. 65 Lower Leeson-street, Dublin.
1877. *Molloy, Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1884. ‡Monaghan, Patrick. Halifax (Box 317), Nova Scotia, Canada.
1887. *Mond, Ludwig, F.C.S. 20 Avenue-road, Regent's Park, London, N.W.
1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
1882. *Montagu, Samuel, M.P. 12 Kensington Palace-gardens, London, W.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, London, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1884. ‡Moore, George Frederick. 25 Marlborough-road, Tue Brook, Liverpool.
1881. §Moore, Henry. Collingham, Maresfield-gardens, Fitzjohn's-avenue, London, N.W.
1890. §Moore, Major. School of Military Engineering, Chatham.

Year of Election.

*MOORE, JOHN CARRICK, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.
1854. ‡MOORE, THOMAS JOHN, Cor. M.Z.S. Free Public Museum, Liverpool.
1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.
1877. ‡Moore, William Vanderkemp. 15 Princess-square, Plymouth.
1871. ‡MORE, ALEXANDER G., F.L.S., M.R.I.A. 74 Leinster-road, Dublin.
1881. ‡MORGAN, ALFRED. 50 West Bay-street, Jacksonville, Florida, U.S.A.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, London, S.W.
1885. ‡Morgan, John. 57 Thomson-street, Aberdeen.
1887. ‡Morgan, John Gray. 38 Lloyd-street, Manchester.
1882. §Morgan, Thomas. Cross House, Southampton.
1878. ‡MORGAN, WILLIAM, Ph.D., F.C.S. Swansea.
1889. §Morison, J. Rutherford, M.D. 14 Saville-row, Newcastle-upon-Tyne.
1867. ‡Morison, William R. Dundee.
1883. *Morley, Henry Forster, M.A., D.Sc., F.C.S. 29 Kylemore-road, West Hampstead, London, N.W.
1889. ‡MORLEY, The Right Hon. JOHN, LL.D., M.P. 95 Elm Park-gardens, London, S.W.
1881. ‡Morrell, W. W. York City and County Bank, York.
1880. ‡Morris, Alfred Arthur Vennor. Wernolau, Cross Inn R.S.O., Carmarthenshire.
1883. ‡Morris, C. S. Millbrook Iron Works, Landore, South Wales.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
1883. ‡Morris, George Lockwood. Millbrook Iron Works, Swansea.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1883. ‡Morris, John. 40 Wellesley-road, Liverpool.
1888. ‡Morris, J. W., F.L.S. The Woodlands, Bathwick Hill, Bath.
1880. ‡Morris, M. I. E. The Lodge, Penclawdd, near Swansea.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1876. ‡Morris, Rev. S. S. O., M.A., R.N., F.C.S. H.M.S. 'Garnet,' S. Coast of America.
1874. ‡Morrison, G. J., M.Inst.C.E. 5 Victoria-street, Westminster, S.W.
1890. §Morrison, Sir George W. Municipal Buildings, Leeds.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1886. ‡Morrison, John T. Scottish Marine Station, Granton, N.B.
1865. ‡Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §MORTON, GEORGE H., F.G.S. 209 Edge-lane, Liverpool.
1858. *MORTON, HENRY JOSEPH. 2 Westbourne-villas, Scarborough.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1887. §Morton, Percy, M.A. Illtyd House, Brecon, South Wales.
1886. *Morton, P. F. 22 Granard-road, Wandsworth Common, Surrey, S.W.
1868. ‡MOSELEY, H. N., M.A., LL.D., F.R.S. Firwood, Clevedon, Somerset.
1883. ‡Moseley, Mrs. Stretton Court, Parkstone, Dorset.
Mosley, Sir Oswald, Bart., D.C.L. Rolleston Hall, Burton-upon-Trent, Staffordshire.
1878. *Moss, JOHN FRANCIS, F.R.G.S. Beechwood, Brincliffe, Sheffield.
1876. §Moss, RICHARD JACKSON, F.C.S., M.R.I.A. St. Aubin's, Ballybrack, Co. Dublin.
1864. *Mosse, J. R. Conservative Club, London, S.W.

Year of Election.

1873. ‡Mossman, William. Ovenden, Halifax.
1869. §Mott, Albert J., F.G.S. Detmore, Charlton Kings, Cheltenham.
1865. ‡*Mott, Charles Grey. The Park, Birkenhead.*
1866. §Mott, Frederick T., F.R.G.S. Birstall Hill, Leicester.
1862. *Mouat, Frederick John, M.D., Local Government Inspector. 12 Durham-villas, Campden Hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. Fulmodeston Rectory, Dereham, Norfolk.
1878. *Moulton, J. Fletcher, M.A., Q.C., F.R.S. 57 Onslow-square, London, S.W.
1863. ‡Mounsey, Edward. Sunderland.
1861. *Mountcastle, William Robert. Bridge Farm, Ellenbrook, near Manchester.
1877. ‡Mount-Edgcumbe, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.
1887. ‡Moxon, Thomas B. County Bank, Manchester.
1888. ‡Moyle, R. E., B.A., F.C.S. The College, Bath.
1886. *Moyles, Mrs. Thomas. The Beeches, Ladywood-road, Edgbaston, Birmingham.
1884. ‡Moyse, C. E., B.A., Professor of English Language and Literature in McGill College, Montreal. 802 Sherbrooke-street, Montreal, Canada.
1884. ‡Moyse, Charles E. 802 Sherbrooke-street, Montreal, Canada.
1876. *Muir, John. 6 Park-gardens, Glasgow.
1874. ‡Muir, M. M. Pattison, M.A., F.R.S.E. Caius College, Cambridge.
1876. ‡Muir, Thomas, M.A., LL.D., F.R.S.E. Beechcroft, Bothwell, Glasgow.
1884. *Muir, William Ker. Detroit, Michigan, U.S.A.
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. Cowley-street, Westminster, S.W.
1876. *Muirhead, Robert Franklin, M.A., B.Sc. Lochwinnoch, Renfrewshire.
1884. *Muirhead-Paterson, Miss Mary. Laurieville, Queen's Drive, Crosshill, Glasgow.
1883. §Mulhall, Michael G. Fancourt, Balbriggan, Co. Dublin.
1883. ‡Mulhall, Mrs. Marion. Fancourt, Balbriggan, Co. Dublin.
1884. *Müller, Hugo, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, London, N.W.
1880. ‡Muller, Hugo M. 1 Grünanger-gasse, Vienna.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡Mundella, The Right Hon. A. J., M.P., F.R.S., F.R.G.S. 16 Elvaston-place, London, S.W.
1876. ‡Munro, Donald, F.C.S. The University, Glasgow.
1885. ‡Munro, J. E. Crawford, LL.D., Professor of Political Economy in Owens College, Manchester.
1883. *Munro, Robert, M.A., M.D. 48 Manor-place, Edinburgh.
1872. *Munster, H. Sillwood Lodge, Brighton.
1864. ‡Murch, Jerom. Cranwells, Bath.
1859. *Murchison, J. H. 25–35 New Broad-street, London, E.C.
1864. *Murchison, K. R. Brockhurst, East Grinstead.
1855. ‡Murdoch, James B. Hamilton-place, Langside, Glasgow.
1890. §Murphy, A. J. Preston House, Leeds.
1889. ‡Murphy, James, M.A., M.D. Holly House, Sunderland.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1884. §Murphy, Patrick. Newry, Ireland.
1887. ‡Murray, A. Hazeldean, Kersal, Manchester.
1869. ‡Murray, Adam. 78 Manor Road, Brockley, S.E.

Year of Election.

Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1859. ‡Murray, John, M.D. Forres, Scotland.
1884. ‡MURRAY, JOHN, F.R.S.E. 'Challenger' Expedition Office, Edinburgh.
1884. ‡Murray, J. Clark, LL.D., Professor of Logic and Mental and Moral Philosophy in McGill University, Montreal. 111 McKay-street, Montreal, Canada.
1872. ‡Murray, J. Jardine, F.R.C.S.E. 99 Montpellier-road, Brighton.
1863. ‡Murray, William, M.D. 34 Clayton-street, Newcastle-on-Tyne.
1883. ‡Murray, W. Vaughan. 4 Westbourne-crescent, Hyde Park, London, W.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1890. *Myres, John L. Swanbourne, Winslow, Buckinghamshire.

1886. §Nagel, D. H., M.A. Trinity College, Oxford.
1890. §Nalder, Francis Henry. 16 Red Lion-street, Clerkenwell, London, E.C.
1876. ‡Napier, James S. 9 Woodside-place, Glasgow.
1872. ‡Nares, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. St. Bernard's, Maple-road, Surbiton.
1887. ‡Nason, Professor Henry B., Ph.D., F.C.S. Troy, New York, U.S.A.
1886. §Neale, E. Vansittart. 14 City-buildings, Corporation-street, Manchester.
1887. §Neild, Charles. 19 Chapel Walks, Manchester.
1883. *Neild, Theodore, B.A. Dalton Hall, Manchester.
1887. ‡Neill, Joseph S. Claremont, Broughton Park, Manchester.
1887. ‡Neill, Robert, jun. Beech Mount, Higher Broughton, Manchester.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1876. ‡Nelson, D. M. 11 Bothwell-street, Glasgow.
1888. ‡Nelson, The Right Rev. the Bishop of, D.D. Nelson, New Zealand.
1886. ‡Nettlefold, Edward. 51 Carpenter-road, Edgbaston, Birmingham.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. §Neville, F. H. Sidney College, Cambridge.
1857. ‡*Neville, John, M.R.I.A. Roden-place, Dundalk, Ireland.*
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
1889. *Newall, H. Frank. Trumpington, Cambridge.
1886. ‡Newbolt, F. G. Edenhurst, Addlestone, Surrey.
1842. *NEWMAN, Professor FRANCIS WILLIAM. 15 Arundel-crescent, Weston-super-Mare.
1889. §Newstead, A. H. L. Roseacre, Epping.
1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalene College, Cambridge.
1883. ‡*Newton, A. W. 7a Westcliffe-road, Birkdale, Southport.*
1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.
1883. ‡Nias, Miss Isabel. 56 Montagu-square, London, W.
1882. ‡Nias, J. B., B.A. 56 Montagu-square, London, W.
1867. ‡Nicholl, Thomas. Dundee.
1875. ‡Nicholls, J. F. City Library, Bristol.
1866. ‡NICHOLSON, Sir CHARLES, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.

Year of Election.

1867. ‡NICHOLSON, HENRY ALLEYNE, M.D., D.Sc., F.G.S., Professor of Natural History in the University of Aberdeen.
1887. *Nicholson, John Carr. Ashfield, Headingley, Leeds.
1884. §Nicholson, Joseph S., M.A., D.Sc., Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.
1883. ‡Nicholson, Richard, J.P. Whinfield, Hesketh Park, Southport.
1887. §Nicholson, Robert H. Bourchier. 21 Albion-street, Hull.
1881. ‡Nicholson, William R. Clifton, York.
1887. ‡Nickson, William. Shelton, Sibson-road, Sale, Manchester.
1885. §Nicol, W. W. J., M.A., D.Sc., F.R.S.E. Mason Science College, Birmingham.
1878. ‡Niven, Charles, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. 6 Chanonry, Aberdeen.
1886. ‡Niven George. Erkingholme, Coolhurst-road, London, N.
1877. ‡Niven, James, M.A. King's College, Aberdeen.
1874. ‡Nixon, Randal C. J., M.A. Royal Academical Institution, Belfast.
1884. ‡Nixon, T. Alcock. 33 Harcourt-street, Dublin.
1863. *NOBLE, Captain ANDREW, C.B., F.R.S., F.R.A.S., F.C.S. Elswick Works, Newcastle-upon-Tyne.
1880. ‡*Noble, John. Rossenstein, Thornhill-road, Croydon, Surrey.*
1879. ‡Noble, T. S., F.G.S. Lendal, York.
1886. §Nock, J. B. Mayfield, Chester-road, Sutton Coldfield.
1887. ‡Nodal, John H. The Grange, Heaton Moor, near Stockport.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1882. §Norfolk, F. 16 Carlton-road, Southampton.
1863. ‡NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., F.R.S., F.L.S. Burnmoor Rectory, Fence Houses, Co. Durham.
1888. ‡Norman, George. 12 Brock-street, Bath.
Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William G. Coalbrookdale, Shropshire.
1881. §North, Samuel William, M.R.C.S., F.G.S. 84 Micklegate, York.
1881. ‡*North, William, B.A., F.C.S. 28 Regent's Park-road, London, N.W.*
*NORTHWICK, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
NORTON, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, London, S.W.; and Hamshall, Birmingham.
1886. ‡Norton, Lady. 35 Eaton-place, London, S.W.; and Hamshall, Birmingham.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of. Norwich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1883. ‡*Nunnerley, John. 46 Alexandra-road, Southport.*
1887. §Nursey, Perry Fairfax. 161 Fleet-street, London, E.C.
1883. *Nutt, Miss Lilian. Rosendale Hall, West Dulwich, London, S.E.

1882. §Obach, Eugene, Ph.D. 2 Victoria-road, Old Charlton, Kent.
O'Callaghan, George. Tallas, Co. Clare.
1888. ‡*O'Connell, Major-General P. 2 College-road, Lansdowne, Bath.*
1878. ‡O'Conor Don, The. Clonalis, Castlerea, Ireland.
1883. ‡Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, London, E.C.

Year of Election.

1858. *Odling, William, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1884. ‡Odlum, Edward, M.A. Pembroke, Ontario, Canada.
1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.
1877. ‡Ogden, Joseph. 13 Hythe-villas, Limes-road, Croydon.
1885. ‡Ogilvie, Alexander, LL.D. Gordon's College, Aberdeen.
1876. ‡Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1885. ‡Ogilvie, F. Grant, M.A., B.Sc. Gordon's College, Aberdeen.
1859. ‡Ogilvy, Rev. C. W. Norman. Baldovan House, Dundee.
*Ogle, William, M.D., M.A. The Elms, Derby.
1884. ‡O'Halloran, J. S., F.R.G.S. Royal Colonial Institute, Northumberland-avenue, London, W.C.
1881. ‡Oldfield, Joseph. Lendal, York.
1887. ‡Oldham, Charles. Syrian House, Sale, near Manchester.
1853. ‡Oldham, James, M.Inst.C.E. Cottingham, near Hull.
1885. ‡Oldham, John. River Plate Telegraph Company, Monte Video.
1863. ‡Oliver, Daniel, F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. Royal Gardens, Kew, Surrey.
1887. §Oliver, F. W., D.Sc. 10 Kew Gardens-road, Kew, Surrey.
1883. ‡Oliver, J. A. Westwood. The Liberal Club, Glasgow.
1883. §Oliver, Samuel A. Bellingham House, Wigan, Lancashire.
1889. §Oliver, Professor T., M.D. Eldon-square, Newcastle-upon-Tyne.
1882. §Olsen, O. T., F.R.A.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
*Ommanney, Admiral Sir Erasmus, C.B., LL.D., F.R.S., F.R.A.S., F.R.G.S. 29 Connaught-square, Hyde Park, London, W.
1880. *Ommanney, Rev. E. A. 123 Vassal-road, Brixton, London, S.W.
1887. §O'Neill, Charles. Glen Allan, Manley-road, Alexandra Park, Manchester.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1883. ‡Oppert, Gustav, Professor of Sanskrit. Madras.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1883. ‡Ord, Miss Maria. Fern Lea, Park-crescent, Southport.
1883. ‡Ord, Miss Sarah. Fern Lea, Park-crescent, Southport.
1880. ‡O'Reilly, J. P., Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham Hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1883. ‡Orpen, Miss. 58 Stephen's-green, Dublin.
1884. *Orpen, Major R. T., R.E. Gibraltar.
1884. *Orpen, Rev. T. H., M.A. Binnbrooke, Cambridge.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1873. ‡Osborn, George. 47 Kingscross-street, Halifax.
1887. §O'Shea, L. J., B.Sc. Firth College, Sheffield.
*Osler, A. Follett, F.R.S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. Coppy Hill, Linthurst, near Bromsgrove, Birmingham.
1869. *Osler, Sidney F. Chesham Lodge, Lower Norwood, Surrey, S.E.
1884. ‡Osler, William, M.D., Professor of the Institutes of Medicine in McGill University, Montreal, Canada.
1884. ‡O'Sullivan, James, F.C.S. 71 Spring Terrace-road, Burton-on-Trent.
1882. *Oswald, T. R. Castle Hall, Milford Haven.
1881. *Ottewell, Alfred D. 83 Siddals-road, Derby.

Year of Election.

1882. ‡Owen, Rev. C. M., M.A. St. George's, Edgbaston, Birmingham.
1889. *Owen, Alderman H. C. Compton, Wolverhampton.
Owen, Sir Richard, K.C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E. Sheen Lodge, Mortlake, Surrey, S.W.
1888. *Owen, Thomas. 8 Alfred-street, Bath.
1877. ‡Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

1889. ‡Page, Dr. F. 1 Saville-place, Newcastle-upon-Tyne.
1883. ‡Page, George W. Fakenham, Norfolk.
1883. ‡Page, Joseph Edward. 12 Saunders-street, Southport.
1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.
1884. ‡Paine, Cyrus F. Rochester, New York, U.S.A.
1875. ‡Paine, William Henry, M.D., F.G.S. Stroud, Gloucestershire.
1870. *Palgrave, R. H. Inglis, F.R.S., F.S.S. Belton, Great Yarmouth.
1883. ‡Palgrave, Mrs. R. H. Inglis. Belton, Great Yarmouth.
1889. ‡Palmer, Sir Charles Mark, Bart., M.P. Grinkle Park, Yorkshire.
1873. ‡Palmer, George, M.P. The Acacias, Reading, Berks.
1878. *Palmer, Joseph Edward. Lyons Mills, Straffan Station, Dublin.
1887. *Palmer, Miss Mary Kate. Kilburn House, Sherwood, Notts.
1866. §Palmer, William. Kilbourne House, Cavendish Hill, Sherwood, Nottinghamshire.
1872. *Palmer, W. R. 1 The Cloisters, Temple, E.C.
Palmes, Rev. William Lindsay, M.A. Naburn Hall, York.
1890. §Pankhurst, R. M., LL.D. 8 Russell-square, London, W.C.
1883. §Pant, F. J. van der. Clifton Lodge, Kingston-on-Thames.
1886. ‡Panton, George A., F.R.S.E. 73 Westfield-road, Edgbaston, Birmingham.
1884. §Panton, Professor J. Hoyes, M.A., F.G.S. Ontario Agricultural College, Guelph, Ontario, Canada.
1883. ‡Park, Henry. Wigan.
1883. ‡Park, Mrs. Wigan.
1880. *Parke, George Henry, F.L.S., F.G.S. College-grove, Wakefield, Yorkshire.
1863. ‡Parker, Henry. Low Elswick, Newcastle-upon-Tyne.
1863. ‡Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-upon-Tyne.
1874. ‡Parker, Henry R., LL.D. Methodist College, Belfast.
Parker, Richard. Dunscombe, Cork.
1886. ‡Parker, Lawley. Chad Lodge, Edgbaston, Birmingham.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling, F.L.S. 6 St. Mary's-row, Birmingham.
1864. ‡*Parkes, William. 23 Abingdon-street, Westminster, S.W.*
1879. §Parkin, William, F.S.S. The Mount, Sheffield.
1887. §Parkinson, James. Station-road, Turton, Bolton.
1859. ‡Parkinson, Robert, Ph.D. Yewbarrow House, Grange-over-Sands.
1841. Parnell, Edward A., F.C.S. Ashley Villa, Swansea.
1862. *Parnell, John, M.A. 1 The Common, Upper Clapton, London, E.
1883. ‡Parson, T. Cooke, M.R.C.S. Atherston House, Clifton, Bristol.
1877. ‡Parson, T. Edgcumbe. 36 Torrington-place, Plymouth.
1865. *Parsons, Charles Thomas. Norfolk-road, Edgbaston, Birmingham.
1878. ‡Parsons, Hon. C. A. Elvaston Hall, Newcastle-upon-Tyne.
1878. ‡*Parsons, Hon. and Rev. R. C. 10 Connaught-place, London, W.*
1883. ‡Part, Isabella. Rudleth, Watford, Herts.
1875. ‡Pass, Alfred C. Rushmere House, Durdham Down, Bristol.
1881. §Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.

Year of Election.

1884. *Paton, David. Johnstone, Scotland.
1883. *Paton, Henry, M.A. 15 Myrtle-terrace, Edinburgh.
1884. *Paton, Hugh. 992 Sherbrooke-street, Montreal, Canada.
1883. ‡Paton, Rev. William. The Ferns, Parkside, Nottingham.
1887. ‡Paterson, A. M., M.D. Owens College, Manchester.
1871. *Patterson, A. Henry. 3 New-square, Lincoln's Inn, London, W.C.
1884. ‡Patterson, Edward Mortimer. Fredericton, New Brunswick, Canada.
1876. §Patterson, T. L. Belmont, Margaret-street, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1889. ‡Pattinson, H. L., jun. Felling Chemical Works, Felling-upon-Tyne.
1863. ‡PATTINSON, JOHN, F.C.S. 75 The Side, Newcastle-upon-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-upon-Tyne.
1867. §Pattison, Samuel Rowles, F.G.S. 11 Queen Victoria-street, London, E.C.
1864. ‡*Pattison, Dr. T. H. London-street, Edinburgh.*
1879. *Patzer, F. R. Stoke-on-Trent.
1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1883. ‡*Paul, G., F.G.S. Filey, Yorkshire.*
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S. 35 Grosvenor-street, London, W.
1887. ‡Paxman, James. Hill House, Colchester.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1881. ‡Payne, J. Buxton. 15 Mosley-street, Newcastle-upon-Tyne.
1877. *Payne, J. C. Charles. Botanic-avenue, The Plains, Belfast.
1881. ‡Payne, Mrs. Botanic-avenue, The Plains, Belfast.
1866. ‡Payne, Dr. Joseph F. 78 Wimpole-street, London, W.
1888. *Paynter, J. B. Hendford Manor House, Yeovil.
1886. ‡Payton, Henry. Eversleigh, Somerset-road, Birmingham.
1876. ‡Peace, G. H. Monton Grange, Eccles, near Manchester.
1879. ‡Peace, William K. Moor Lodge, Sheffield.
1885. ‡Peach, B. N., F.R.S.E., F.G.S. Geological Survey Office, Edinburgh.
1883. ‡Peacock, Ebenezer. 8 Mandeville-place, Manchester-square, London, W.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C.
1881. *PEARCE, HORACE, F.R.A.S., F.L.S., F.G.S. The Limes, Stourbridge.
1886. *Pearce, Mrs. Horace. The Limes, Stourbridge.
1888. §Pearce, Rev. R. J., D.C.L., Professor of Mathematics in the University of Durham. St. Giles's Vicarage, Durham.
1884. ‡Pearce, William. Winnipeg, Canada.
1886. ‡Pearsall, Howard D. 3 Cursitor-street, London, E.C.
1887. ‡Pearse, J. Walter. Brussels.
1881. ‡Pearse, Richard Seward. Southampton.
1883. ‡Pearson, Arthur A. Colonial Office, London, S.W.
1883. ‡Pearson, Miss Helen E. 69 Alexandra-road, Southport.
1881. ‡Pearson, John. Glentworth House, The Mount, York.
1883. ‡Pearson, Mrs. Glentworth House, The Mount, York.
1872. *Pearson, Joseph. Grove Farm, Merlin, Raleigh, Ontario, Canada.
1881. ‡Pearson, Richard. 23 Bootham, York.
1870. ‡Pearson, Rev. Samuel, M.A. Highbury-quadrant, London, N.
1883. *Pearson, Thomas H. Redclyffe, Newton-le-Willows, Lancashire.
1863. §Pease, H. F. Brinkburn, Darlington.
1889. ‡Pease, Howard. Enfield Lodge, Benwell, Newcastle-upon-Tyne.
1863. ‡Pease, Sir Joseph W., Bart., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-upon-Tyne.

Year of Election.

1883. ‡Peck, John Henry. 52 Hoghton-street, Southport.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
*Peckover, Algernon, F.L.S. Sibald's Holme, Wisbech, Cambridgeshire.
1885. ‡Peddie, W. Spring Valley Villa, Morningside-road, Edinburgh.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1883. ‡Peek, C. E. Conservative Club, London, S.W.
1878. *Peek, William. 16 Belgrave-place, Brighton.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, London, S.W.
1884. ‡Pegler, Alfred. Elmfield, Southampton.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, London, W.C.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, Sir John, K.C.M.G. 18 Arlington-street, London, S.W.
1887. §Pendlebury, William H. 6 Gladstone-terrace, Priory Hill, Dover.
1856. §PENGELLY, WILLIAM, F.R.S., F.G.S. Lamorna, Torquay.
1881. ‡Penty, W. G. Melbourne-street, York.
1875. ‡Perceval, Rev. Canon John, M.A., LL.D. Rugby.
1889. §Percival, Archibald Stanley, M.A., M.B. 6 Lovaine-crescent, Newcastle-upon-Tyne.
*Perigal, Frederick. Cambridge Cottage, Kingswood, Reigate.
1886. ‡Perkin, T. Dix. Greenford Green, Harrow, Middlesex.
1868. *PERKIN, WILLIAM HENRY, Ph.D., F.R.S., F.C.S. The Chestnuts, Sudbury, Harrow, Middlesex.
1884. ‡Perkin, William Henry, jun., Ph.D., F.R.S., F.C.S., Professor of Chemistry in the Heriot Watt College, Edinburgh.
1877. ‡Perkins, Loftus. Seaford-street, Regent-square, London, W.C.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1885. §Perrin, Miss Emily. 31 St John's Wood Park, London, N.W.
1886. ‡Perrin, Henry S. 31 St. John's Wood Park, London, N.W.
1886. ‡Perrin, Mrs. 23 Holland Villas-road, Kensington, London, W.
Perry, The Right Rev. Charles, M.A., D.D. 32 Avenue-road, Regent's Park, London, N.W.
1879. ‡Perry, James. Roscommon.
1874. *PERRY, JOHN, M.E., D.Sc., F.R.S., Professor of Engineering and Applied Mathematics in the Technical College, Finsbury. 31 Brunswick-square, London, W.C.
1883. ‡Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.
1883. ‡Perry, Russell R. 34 Duke-street, Brighton.
1886. ‡*Perry, William. Hanbury Villa, Stourbridge.*
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 5 Fourth-avenue, Brighton.
1882. ‡Pfoundes, Charles. Spring Gardens, London, S.W.
1886. ‡Phelps, Colonel A. 23 Augustus-road, Edgbaston, Birmingham.
1884. ‡Phelps, Charles Edgar. Carisbrooke House, The Park, Nottingham.
1884. ‡Phelps, Mrs. Carisbrooke House, The Park, Nottingham.
1886. ‡Phelps, Hon. E. J. American Legation, Members' Mansions, Victoria-street, London, S.W.
1886. ‡Phelps, Mrs. Hamshall, Birmingham.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.

Year of Election.

1853. *Philips, Herbert. The Oak House, Macclesfield.
1877. §Philips, T. Wishart. Dunedin, Wanstead, Essex.
1863. ‡Philipson, Dr. 7 Eldon-square, Newcastle-upon-Tyne.
1889. ‡Philipson, John. 9 Victoria-square, Newcastle-upon-Tyne.
1883. ‡Phillips, Arthur G. 20 Canning-street, Liverpool.
1862. ‡Phillips, Rev. George, D.D. Queen's College, Cambridge.
1887. ‡Phillips, H. Harcourt, F.C.S. 18 Exchange-street, Manchester.
1880. §Phillips, John H., Hon. Sec. Philosophical and Archæological Society, Scarborough.
1883. ‡*Phillips, Mrs. Leah R. 1 East Park-terrace, Southampton.*
1890. §Phillips, R. W., M.A., Professor of Biology in University College, Bangor.
1883. ‡Phillips, S. Rees. Wonford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
PHILPOTT, Right Rev. HENRY, D.D. The Elms, Cambridge.
1868. ‡PHIPSON, T. L., Ph.D., F.C.S. 4 The Cedars, Putney, Surrey, S.W.
1884. *Pickard, Rev. H. Adair, M.A. 5 Canterbury-road, Oxford.
1883. *Pickard, Joseph William. Lindow Cottage, Lancaster.
1885. *PICKERING, SPENCER U., M.A., F.R.S. 48 Bryanston-square, London, W.
1884. *Pickett, Thomas E., M.D. Maysville, Mason County, Kentucky, U.S.A.
1888. *Pidgeon, W. R. 42 Porchester-square, London, W.
1871. ‡Pigot, Thomas F., M.R.I.A. Royal College of Science, Dublin.
1884. ‡Pike, L. G., M.A., F.Z.S. 4 The Grove, Highgate, London, N.
1865. ‡PIKE, L. OWEN. 201 Maida-vale, London, W.
1873. ‡Pike, W. H. University College, Toronto, Canada.
1857. ‡Pilkington, Henry M., LL.D., Q.C. 45 Upper Mount-street, Dublin.
1883. ‡Pilling, R. C. The Robin's Nest, Blackburn.
Pim, George, M.R.I.A. Brenanstown, Cabinteely, Co. Dublin.
1877. ‡Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡PIRIE, Rev. G., M.A., Professor of Mathematics in the University of Aberdeen. 33 College Bounds, Old Aberdeen.
1884. ‡Pirz, Anthony. Long Island, New York, U.S.A.
1887. ‡Pitkin, James. 56 Red Lion-street, Clerkenwell, London, E.C.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1883. ‡Pitt, George Newton, M.A., M.D. 34 Ashburn-place, South Kensington, London, S.W.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1883. §Pitt, Sydney. 34 Ashburn-place, South Kensington, London, S.W.
1868. ‡PITT-RIVERS, Lieut.-General A. H. L., D.C.L., F.R.S., F.G.S., F.S.A. 4 Grosvenor-gardens, London, S.W.
1872. ‡Plant, Mrs. H. W. 28 Evington-street, Leicester.
1869. ‡PLANT, JAMES, F.G.S. 40 West-terrace, West-street, Leicester.
1886. ‡*Player, J. H. 5 Prince of Wales-terrace, Kensington, London, W.*
1842. PLAYFAIR, The Right Hon. Sir LYON, K.C.B., Ph.D., LL.D., M.P., F.R.S. L. & E., F.C.S. 68 Onslow-gardens, South Kensington, London, S.W.
1867. ‡PLAYFAIR, Lieut.-Colonel Sir R. L., K.C.M.G., H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, London, S.W.)
1884. *Playfair, W. S., M.D., LL.D., Professor of Midwifery in King's College, London. 31 George-street, Hanover-square, London, W.
1883. *Plimpton, R. T., M.D. 23 Lansdowne-road, Clapham-road, London, S.W.

Year of Election.

1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *Pochin, Henry Davis, F.C.S. Bodnant Hall, near Conway.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1888. ‡Pocock, Rev. Francis. 4 Brunswick-place, Bath.
1846. ‡Pole, William, Mus.Doc., F.R.S., M.Inst.C.E. Athenæum Club, Pall Mall, London, S.W.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1868. ‡Portal, Wyndham S. Malshanger, Basingstoke.
1883. *Porter, Rev. C. T., LL.D. Brechin Lodge, Cambridge-road, Southport.
1886. ‡Porter, Paxton. Birmingham and Midland Institute, Birmingham.
1866. ‡*Porter, Robert. Highfield, Long Eaton, Nottingham.*
1888. ‡*Porter, Robert. Westfield House, Bloomfield-road, Bath.*
1883. ‡Postgate, Professor J. P., M.A. Trinity College, Cambridge.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
1887. ‡Potter, Edmund P. Hollinhurst, Bolton.
1883. ‡Potter, M. C., M.A., F.L.S. St. Peter's College, Cambridge.
1883. §Potts, John. 33 Chester-road, Macclesfield.
1886. *Poulton, Edward B., M.A., F.R.S., F.L.S. Wykeham House, Oxford.
1873. *Powell, Francis S., M.P., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1887. *Powell, Horatio Gibbs. Wood Villa, Tettenhall Wood, Wolverhampton.
1883. ‡Powell, John. Waunarlwydd House, near Swansea.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1887. §Pownall, George H. Manchester and Salford Bank, Mosley-street, Manchester.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuk, Uddingston, Scotland.
1883. ‡Poynting, J. H., M.A., F.R.S., Professor of Physics in the Mason College, Birmingham. 11 St. Augustine's-road, Birmingham.
1884. §Prance, Courtenay C. Hatherley Court, Cheltenham.
1884. *Prankerd, A. A., D.C.L. Brazenose College, Oxford.
1869. *Preece, William Henry, F.R.S., M.Inst.C.E. Gothic Lodge, Wimbledon Common, Surrey.
1888. *Preece, W. L. St. James's-terrace, London-road, Derby.
1884. *Premio-Real, His Excellency the Count of. Quebec, Canada.
1889. §Preston, Alfred Eley. 14 The Exchange, Bradford, Yorkshire.
*Prestwich, Joseph, M.A., D.C.L., F.R.S., F.G.S., F.C.S. Shoreham, near Sevenoaks.
1884. *Prevost, Major L. de T. 2nd Battalion Argyll and Sutherland Highlanders.
1856. *Price, Rev. Bartholomew, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford. 11 St. Giles's, Oxford.
1882. ‡Price, John E., F.S.A. 27 Bedford-place, Russell-square, London, W.C.
Price, J. T. Neath Abbey, Glamorganshire.
1888. §Price, L. L. F. R., M.A., F.S.S. Oriel College, Oxford.
1881. §Price, Peter. 12 Windsor-place, Cardiff.
1875. *Price, Rees. 163 Bath-street, Glasgow.

Year of Election.

1875. *Price, William Philip. Tibberton Court, Gloucester.
1876. ‡Priestley, John. 174 Lloyd-street, Greenheys, Manchester.
1875. ‡Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.
1883. ‡Prince, Thomas. Horsham-road, Dorking.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1846. *PRITCHARD, Rev. CHARLES, D.D., F.R.S., F.G.S., F.R.A.S., Professor of Astronomy in the University of Oxford. 8 Keble-terrace, Oxford.
1889. *Pritchard, Eric Law. 12 Alwyne-place, Canonbury, London, N.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 3 George-street, Hanover-square, London, W.
1888. ‡Probyn, Leslie C. Onslow-square, London, S.W.
1881. §Procter, John William. Ashcroft, Nunthorpe, York.
1863. ‡Proctor, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1885. ‡Profeit, Dr. Balmoral, N.B.
1863. ‡Proud, Joseph. South Hetton, Newcastle-upon-Tyne.
1884. *Proudfoot, Alexander, M.D. 2 Phillips-place, Montreal, Canada.
1879. *Prouse, Oswald Milton, F.G.S., F.R.G.S. Alvington, Slade-road, Ilfracombe.
1865. ‡*Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.*
1872. *Pryor, M. Robert. Weston Manor, Stevenage, Herts.
1871. *Puckle, Thomas John. 42 Cadogan-place, London, S.W.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Tayside, Perth.
1842. *Pumphrey, Charles. Southfield, King's Norton, near Birmingham.
1887. §PUMPHREY, WILLIAM. Lyncombe, Bath.
1885. §Purdie, Thomas, B.Sc., Ph.D., Professor of Chemistry in the University of St. Andrews. St. Andrews, N.B.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1882. ‡Purrott, Charles. West End, near Southampton.
1874. ‡PURSER, FREDERICK, M.A. Rathmines, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., M.R.I.A. Queen's College, Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1884. *Purves, W. Laidlaw. 20 Stafford-place, Oxford-street, London, W.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1883. §Pye-Smith, Arnold. 16 Fairfield-road, Croydon.
1883. §Pye-Smith, Mrs. 16 Fairfield-road, Croydon.
1868. ‡PYE-SMITH, P. H., M.D., F.R.S. 54 Harley-street, W.; and Guy's Hospital, London, S.E.
1879. §Pye-Smith, R. J. 350 Glossop-road, Sheffield.
1861. *Pyne, Joseph John. The Willows, Albert-road, Southport.

1888. ‡Quin, J. A., J.P. 14 South-parade, Bath.

1870. ‡Rabbits, W. T. Forest Hill, London, S.E.
1887. §Rabone, John. Penderell House, Hamstead-road, Birmingham.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1877. ‡Radford, George D. Mannamead, Plymouth.
1879. ‡Radford, R. Heber. Wood Bank, Pitsmoor, Sheffield.
*Radford, William, M.D. Sidmount, Sidmouth.
1855. *Radstock, The Right Hon. Lord. 70 Portland-place, London, W.
1888. ‡Radway, C. W. 9 Bath-street, Bath.

Year of Election.

1878. ‡RAE, JOHN, M.D., LL.D., F.R.S., F.R.G.S. 4 Addison-gardens, Kensington, London, W.

1887. *Ragdale, John Rowland. Derby-place, Whitefield, Manchester.

1864. ‡Rainey, James T. St. George's Lodge, Bath.

Rake, Joseph. Charlotte-street, Bristol.

1885. ‡Ramsay, Major. Straloch, N.B.

1863. ‡RAMSAY, ALEXANDER, F.G.S. 2 Cowper-road, Acton, Middlesex, W.

1845. ‡RAMSAY, Sir ANDREW CROMBIE, LL.D., F.R.S., F.G.S. 7 Victoria-terrace, Beaumaris.

1884. ‡Ramsay, George G., LL.D., Professor of Humanity in the University of Glasgow. 6 The College, Glasgow.

1884. ‡Ramsay, Mrs. G. G. 6 The College, Glasgow.

1861. ‡Ramsay, John. Kildalton, Argyllshire.

1889. ‡Ramsay, Major R. G. W. Bonnyrigg, Edinburgh.

1867. *Ramsay, W. F., M.D. 109 Sinclair-road, West Kensington Park, London, W.

1876. *RAMSAY, WILLIAM, Ph.D., F.R.S., F.C.S., Professor of Chemistry in University College, London, W.C.

1883. ‡Ramsay, Mrs. 12 Arundel-gardens, London, W.

1887. ‡Ramsbottom, John. Fernhill, Alderley Edge, Cheshire.

1873. *Ramsden, William. Bracken Hall, Great Horton, Bradford, Yorkshire.

1835. *Rance, Henry. 6 Ormonde-terrace, Regent's Park, London, N.W.

1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, West Kensington, London, S.W.

1865. ‡Randel, J. 50 Vittoria-street, Birmingham.

1868. *Ransom, Edwin, F.R.G.S. Ashburnham-road, Bedford.

1863. §Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.

1861. ‡Ransome, Arthur, M.A., M.D., F.R.S. Devisdale, Bowdon, Manchester.

Ransome, Thomas. Hest Bank, near Lancaster.

1872. *Ranyard, Arthur Cowper, F.R.A.S. 11 Stone-buildings, Lincoln's Inn, London, W.C.

1889. §Rapkin, J. B. Sidcup, Kent.

Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.

1864. ‡Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.

1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.

1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.

1870. ‡Rathbone, R. R. Beechwood House, Liverpool.

1874. ‡RAVENSTEIN, E. G., F.R.G.S., F.S.S. 91 Upper Tulse-hill, London, S.W.

Rawdon, William Frederick, M.D. Bootham, York.

1889. ‡Rawlings, Edward. Richmond House, Wimbledon Common, Surrey.

1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.

1866. *RAWLINSON, Rev. Canon GEORGE, M.A. The Oaks, Precincts, Canterbury.

1855. *RAWLINSON, Major-General Sir HENRY C., Bart., G.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.

1887. ‡Rawson, Harry. Earlswood, Ellesmere Park, Eccles, Manchester.

1875. §RAWSON, Sir RAWSON W., K.C.M.G., C.B., F.R.G.S. 68 Cornwall-gardens, Queen's-gate, London, S.W.

1886. ‡Rawson, W. Stepney, M.A., F.C.S. 68 Cornwall-gardens, Queen's-gate, London, S.W.

1883. ‡*Ray, Miss Catherine. Mount Cottage, Flask-walk, Hampstead, London, N.W.*

Year of Election.

1868. *RAYLEIGH, The Right Hon. Lord, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S., F.R.G.S., Professor of Natural Philosophy in the Royal Institution, London. Terling Place, Witham, Essex.
1883. *Rayne, Charles A., M.D., M.R.C.S. Queen-street, Lancaster.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.
1870. ‡READE, THOMAS MELLARD, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., D.Sc., F.R.S.E. 9 Moray-place, Edinburgh.
1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1889. ‡Redmayne, J. M. Harewood, Gateshead.
1889. ‡Redmayne, Norman. 26 Grey-street, Newcastle-upon-Tyne.
1888. ‡Rednall, Miss Edith E. Ashfield House, Neston, near Chester.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. ‡REED, Sir EDWARD J., K.C.B., M.P., F.R.S. 75 Harrington-gardens, London, S.W.
1889. ‡Reed, Rev. George. Bellingham Vicarage, Bardon Mill.
1888. ‡Rees, W. L. 11 North-crescent, Bedford-square, London, W.C.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1881. §Reid, Arthur S., B.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *REID, CLEMENT, F.G.S. 28 Jermyn-street, London, S.W.
1889. ‡Reid, George, Belgian Consul. Leazes House, Newcastle-upon-Tyne.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1884. ‡Reid, Rev. James, B.A. Bay City, Michigan, U.S.A.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1850. ‡Reid, William, M.D. Cruivie, Cupar Fife.
1881. ‡Reid, William. 19½ Blake-street, York.
1875. §REINOLD, A. W., M.A., F.R.S., Professor of Physical Science in the Royal Naval College, Greenwich, S.E.
1863. ‡RENALS, E. 'Nottingham Express' Office, Nottingham.
1885. ‡Rennett, Dr. 12 Golden-square, Aberdeen.
1889. *Rennie, George B. Hooley Lodge, Redhill.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1883. *Reynolds, A. H. Manchester and Salford Bank, Southport.
1871. ‡REYNOLDS, JAMES EMERSON, M.D., F.R.S., F.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1870. *REYNOLDS, OSBORNE, M.A., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering in Owens College, Manchester. 23 Lady Barn-road, Fallowfield, Manchester.
1858. §REYNOLDS, RICHARD, F.C.S. 13 Briggate, Leeds.
1887. ‡Rhodes, George W. The Cottage, Victoria Park, Manchester.
1883. ‡Rhodes, Dr. James. 25 Victoria-street, Glossop.
1890. §Rhodes, J. M., M.D. Ivy Lodge, Didsbury.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1888. §Rhodes, John George. Warwick House, 46 St. George's-road, London, S.W.
1884. ‡Rhodes, Lieut.-Colonel William. Quebec, Canada.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Via Stimmate, 15, Modena, Italy.
1889. ‡Richards, Professor T. W., Ph.D. Cambridge, Massachusetts, U.S.A.
1888. *RICHARDSON, ARTHUR, M.D. University College, Bristol.
1863. ‡RICHARDSON, BENJAMIN WARD, M.A., M.D., LL.D., F.R.S. 25 Manchester-square, London, W.
1861. ‡Richardson, Charles. 10 Berkeley-square, Bristol.

Year of Election.

1869. *Richardson, Charles. 4 Northumberland-avenue, Putney, S.W.
1887. *Richardson, Miss Emma. Conway House, Dunmurry, Co. Antrim.
1882. §Richardson, Rev. George, M.A. The College, Winchester.
1884. *Richardson, George Straker. Isthmian Club, 150 Piccadilly, London, W.
1889. §Richardson, Hugh. Sedbergh School, Sedbergh R.S.O., Yorkshire.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1870. ‡Richardson, Ralph, F.R.S.E. 10 Magdala-place, Edinburgh.
1889. ‡Richardson, Thomas, J.P. 7 Windsor-terrace, Newcastle-upon-Tyne.
1881. ‡Richardson, W. B. Elm Bank, York.
1861. ‡Richardson, William. 4 Edward-street, Werneth, Oldham.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1886. §Richmond, Robert. Leighton Buzzard.
1863. ‡Richter, Otto, Ph.D. 407 St. Vincent-street, Glasgow.
1868. ‡Ricketts, Charles, M.D., F.G.S. 18 Hamilton-square, Birkenhead.
1877. ‡Ricketts, James, M.D. St. Helens, Lancashire.
*Riddell, Major-General Charles J. Buchanan, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1883. *Rideal, Samuel. 161 Devonshire-road, Forest Hill, Kent, S.E.
1862. ‡Ridgway, Henry Ackroyd, B.A. Bank Field, Halifax.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1889. §Ridley, Thomas D. Coatham, Redcar.
1884. ‡Ridout, Thomas. Ottawa, Canada.
1863. *Rigby, Samuel. Fern Bank, Liverpool-road, Chester.
1881. *Rigg, Arthur. 71 Warrington-crescent, London, W.
1883. *Rigg, Edward, M.A. Royal Mint, London, E.
1883. ‡Rigg, F. F., M.A. 32 Queen's-road, Southport.
1883. *Rigge, Samuel Taylor, F.S.A. Balmoral-place, Halifax.
1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.
*Ripon, The Most Hon. the Marquis of, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. 9 Chelsea Embankment, London, S.W.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1867. ‡Ritchie, William. Emslea, Dundee.
1889. ‡Ritson, U. A. 1 Jesmond-gardens, Newcastle-upon-Tyne.
1869. *Rivington, John. Babbicombe, near Torquay.
1888. ‡Robb, W. J. Firth College, Sheffield.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *Robbins, John, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
1878. ‡Roberts, Charles, F.R.C.S. 2 Bolton-row, London, W.
1887. *Roberts, Evan. 3 Laurel-bank, Alexandra-road, Manchester.
1859. ‡Roberts, George Christopher. Hull.
1870. *Roberts, Isaac, F.R.S., F.R.A.S., F.G.S. Crowborough, Sussex.
1883. ‡Roberts, Ralph A. 4 Colville Mansions, Powis-terrace, London, W.
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. Clare College, Cambridge.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1883. ‡Roberts, Sir William, M.D., F.R.S. 8 Manchester-square, London, W.
1868. *Roberts-Austen, W. Chandler, C.B., F.R.S., F.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal College of Science, London. Royal Mint, London, E.
1883. ‡Robertson, Alexander. Montreal, Canada.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.

Year of Election.

1884. ‡Robertson, E. Stanley, M.A. 43 Waterloo-road, Dublin.
1871. ‡Robertson, George, M.Inst.C.E., F.R.S.E. 47 Albany-street, Edinburgh.
1883. ‡Robertson, George H. The Nook, Gateacre, near Liverpool.
1883. ‡Robertson, Mrs. George H. The Nook, Gateacre, near Liverpool.
1876. ‡Robertson, R. A. Newthorn, Ayton-road, Pollokshields, Glasgow.
1888. *Robins, Edward Cookworthy, F.S.A. 46 Berners-street, Oxford-street, London, W.
1886. *Robinson, C. R. 27 Elvetham-road, Birmingham.
1886. ‡Robinson, Edward E. 56 Dovey-street, Liverpool.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Beech Hill, Armagh.
1887. ‡Robinson, Henry. 7 Westminster-chambers, London, S.W.
1887. ‡Robinson, James. Akroydon Villa, Halifax, Yorkshire.
1861. ‡Robinson, John, M.Inst.C.E. Atlas Works, Manchester.
1888. §Robinson, John. Engineer's Office, Barry Dock, Cardiff.
1863. ‡Robinson, J. H. 6 Montallo-terrace, Barnard Castle.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1887. §Robinson, Richard. Bellfield Mill, Rochdale.
1881. ‡Robinson, Richard Atkinson. 195 Brompton-road, London, S.W.
1875. *Robinson, Robert, M.Inst.C.E., F.G.S. Beechwood, Darlington.
1884. ‡Robinson, Stillman. Columbus, Ohio, U.S.A.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1888. §Robottom, Arthur. 3 St. Alban's-villas, Highgate-road, London, N.W.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1876. ‡Robson, Hazleton R. 14 Royal-crescent West, Glasgow.
1872. *Robson, William. Marchholm, Gillsland-road, Merchiston, Edinburgh.
1885. §Rodger, Edward. 1 Claremont-gardens, Glasgow.
1885. *Rodriguez, Epifanio. 12 John-street, Adelphi, London, W.C.
1872. ‡Rodwell, George F., F.R.A.S., F.C.S. Marlborough College, Wiltshire.
1866. ‡Roe, Thomas. Grove-villas, Sitchurch.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1890. *Rogers, L. J., M.A., Professor of Mathematics in Yorkshire College, Leeds. 13 Beech Grove-terrace, Leeds.
1883. ‡Rogers, Major R. Alma House, Cheltenham.
1882. §Rogers, Rev. Saltren, M.A. Gwennap, Redruth, Cornwall.
1883. ‡*Rogers, Thomas Stanley, LL.B. 77 Albert-road, Southport.*
1884. *Rogers, Walter M. Lamowa, Falmouth.
1886. ‡Rogers, W. Woodbourne. Wheeley's-road, Edgbaston, Birmingham.
1889. ‡Rogerson, John. Croxdale Hall, Durham.
1876. ‡Rollit, Sir A. K., M.P., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1876. ‡Romanes, George John, M.A., LL.D., F.R.S., F.L.S. St. Aldate's, Oxford.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. *Roper, Freeman Clarke Samuel, F.L.S., F.G.S. Palgrave House, Eastbourne.
1881. *Roper, W. O. Eadenbreck, Lancaster.
1855. *Roscoe, Sir Henry Enfield, B.A., Ph.D., LL.D., D.C.L., M.P., F.R.S., F.C.S. 10 Bramham-gardens, London, S.W.
1883. *Rose, J. Holland, M.A. Aboyne, Bedford Hill-road, Balham, London, S.W.

Year of Election.

1885. ‡Ross, Alexander. Riverfield, Inverness.
1874. ‡Ross, Alexander Milton, M.A., M.D., F.G.S. Toronto, Canada.
1857. ‡Ross, David, LL.D. 32 Nelson-street, Dublin.
1887. ‡Ross, Edward. Marple, Cheshire.
1880. ‡Ross, Captain G. E. A., F.R.G.S. 8 Collingham-gardens, Cromwell-road, London, S.W.
1872. ‡Ross, James, M.D. Tenterfield House, Waterfoot, near Manchester.
1859. *Ross, Rev. James Coulman. Baldon Vicarage, Oxford.
1880. ‡*Ross, Major William Alexander. Acton House, Acton, London, W.*
1869. *Rosse, The Right Hon. the Earl of, K.P., B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1884. *Rouse, M. L. 343 Church-street, Toronto, Canada.
1861. ‡Routh, Edward J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1881. ‡*Routh, Rev. William, M.A. Clifton Green, York.*
1861. ‡Rowan, David. Elliot-street, Glasgow.
1883. ‡Rowan, Frederick John. 134 St. Vincent-street, Glasgow.
1887. ‡Rowe, Rev. Alfred W., M.A., F.G.S. Felstead, Essex.
1881. ‡Rowe, Rev. G. Lord Mayor's Walk, York.
1865. ‡Rowe, Rev. John. 13 Hampton-road, Forest Gate, Essex.
1877. ‡Rowe, J. Brooking, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.
1890. §Rowley, Walter, F.S.A. Alderhill, Meanwood, Leeds.
1855. *Rowney, Thomas H., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway. Salerno, Salthill, Galway.
1881. *Rowntree, Joseph. 37 St. Mary's, York.
1881. *Rowntree, J. S. The Mount, York.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1883. ‡Roy, Charles S., M.D., F.R.S., Professor of Pathology in the University of Cambridge. Trinity College, Cambridge.
1885. ‡Roy, John. 33 Belvidere-street, Aberdeen.
1888. ‡Roy, Parbati Churn, B.A. Calcutta, Bengal, India.
1861. *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.
1875. ‡Rücker, A. W., M.A., F.R.S., Professor of Physics in the Royal College of Science, London. Errington, Clapham Park, London, S.W.
1869. §Rudler, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.
1882. ‡Rumball, Thomas, M.Inst.C.E. 8 Queen Anne's-gate, London, S.W.
1884. §Runtz, John. Linton Lodge, Lordship-road, Stoke Newington, London, N.
1887. §Ruscoe, John, F.G.S. Ferndale, Gee Cross, near Manchester.
1847. ‡Ruskin, John, M.A., F.G.S. Brantwood, Coniston, Ambleside.
1889. §Russell, The Right Hon. Earl. Teddington, Middlesex.
1875. *Russell, The Hon. F. A. R. Pembroke Lodge, Richmond Park, Surrey.
1884. ‡*Russell, George. Hoe Park House, Plymouth.*
1890. §Russell, J. A., M.B. Woodville, Canaan-lane, Edinburgh.
1883. *Russell, J. W. Merton College, Oxford.
Russell, John. 39 Mountjoy-square, Dublin.
1852. *Russell, Norman Scott. Arts Club, Hanover-square, London, W.
1876. §Russell, R., F.G.S. 1 Sea View, St. Bees, Carnforth.
1886. ‡Russell, Thomas H. 3 Newhall-street, Birmingham.

Year of Election.

1862. §Russell, W. H. L., B.A., F.R.S. 50 South-grove, Highgate, London, N.
1852. *Russell, William J., Ph.D., F.R.S., F.C.S., Lecturer on Chemistry in St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.
1886. §Rust, Arthur. Eversleigh, Leicester.
1883. *Ruston, Joseph, M.P. Monk's Manor, Lincoln.
1889. ‡Rutherford, Rev. Dr. 6 Eldon-square, Newcastle-upon-Tyne.
1871. §Rutherford, William, M.D., F.R.S., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.
1887. ‡Rutherford, William. 7 Vine-grove, Chapman-street, Hulme, Manchester.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1879. ‡Ruxton, Vice-Admiral Fitzherbert, R.N., F.R.G.S. 41 Cromwell-gardens, London, S.W.
1875. ‡Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, London, E.C.
1889. §Ryder, W. J. H. 52 Jesmond-road, Newcastle-upon-Tyne.
1886. ‡*Ryland, F. Augustus-road, Edgbaston, Birmingham.*
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *Rylands, Thomas Glazebrook, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

1883. **Sabine, Robert. 3 Great Winchester-street-buildings, London, E.C.*
1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. Purton Court, Purton, near Swindon, Wiltshire.
1885. §Saint, W. Johnston. 11 Queen's-road, Aberdeen.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1886. §St. Clair, George, F.G.S. 127 Bristol-road, Birmingham.
1887. *Salford, the Right Rev. the Bishop of. Bishop's House, Salford.
1881. ‡Salkeld, William. 4 Paradise-terrace, Darlington.
1857. ‡Salmon, Rev. George, D.D., D.C.L., LL.D., F.R.S., Provost of Trinity College, Dublin.
1883. ‡Salmond, Robert G. The Nook, Kingswood-road, Upper Norwood, S.E.
1873. *Salomons, Sir David, Bart. Broomhill, Tunbridge Wells.
1883. ‡*Salt, Shirley H., M.A. 73 Queensborough-terrace, London, W.*
1872. ‡Salvin, Osbert, M.A., F.R.S., F.L.S. Hawksfold, Haslemere.
1887. ‡Samson, C. L. Carmona, Kersal, Manchester.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1861. *Sandeman, Archibald, M.A. Garry Cottage, Perth.
1883. ‡Sandeman, E. 53 Newton-street, Greenock.
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1883. *Sanders, Charles J. B. Pennsylvania, Exeter.
1884. ‡Sanders, Henry. 185 James-street, Montreal, Canada.
1872. ‡*Sanders, Mrs. 8 Powis-square, Brighton.*
1883. ‡Sanderson, Surgeon Alfred. East India United Service Club, St. James's-square, London, S.W.
1872. ‡Sanderson, J. S. Burdon, M.D., LL.D., D.C.L., F.R.S., Professor of Physiology in the University of Oxford. 64 Banbury-road, Oxford.
1883. ‡Sanderson, Mrs. Burdon. 64 Banbury-road, Oxford.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1886. §Sankey, Percy E. Lyndhurst, St. Peter's, Kent.
1886. ‡Sauborn, John Wentworth. Albion, New York, U.S.A.
1886. ‡Saundby, Robert, M.D. 83a Edmund-street, Birmingham.

Year of Election.

1868. ‡Saunders, A., M.Inst.C.E. King's Lynn.
1886. ‡Saunders, C. T. Temple-row, Birmingham.
1881. ‡SAUNDERS, HOWARD, F.L.S., F.Z.S. 7 Radnor-place, London, W.
1883. ‡Saunders, Rev. J. C. Cambridge.
1846. ‡SAUNDERS, TRELAWNEY W., F.R.G.S. 3 Elmfield on the Knowles, Newton Abbot, Devon.
1884. ‡Saunders, William. Experimental Farm, Ottawa, Canada.
1884. ‡Saunderson, C. E. 26 St. Famille-street, Montreal, Canada.
1887. §Savage, Rev. E. B., M.A. St. Thomas' Parsonage, Douglas, Isle of Man.
1871. §Savage, W. D. Ellerslie House, Brighton.
1883. ‡Savage, W. W. 109 St. James's-street, Brighton.
1883. ‡Savery, G. M., M.A. The College, Harrogate.
1872. *Sawyer, George David, F.R.M.S. 55 Buckingham-place, Brighton.
1887. §SAYCE, Rev. A. H., M.A., D.D. Queen's College, Oxford.
1884. ‡Sayre, Robert H. Bethlehem, Pennsylvania, U.S.A.
1883. *Scarborough, George. Holly Bank, Halifax, Yorkshire.
1883. ‡*Scarisbrick, Charles. 5 Palace-gate, Kensington, London, W.*
1884. ‡Scarth, William Bain. Winnipeg, Manitoba, Canada.
1868. §Schacht, G. F. 1 Windsor-terrace, Clifton, Bristol.
1879. *SCHÄFER, E. A., F.R.S., M.R.C.S., Professor of Physiology in University College, London. Croxley Green, Rickmansworth.
1883. ‡Schäfer, Mrs. Croxley Green, Rickmansworth.
1888. §SCHARFF, ROBERT F., Ph.D., B.Sc. Science and Art Museum, Dublin.
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1887. ‡Schofield, T. Thornfield, Talbot-road, Old Trafford, Manchester.
1883. ‡Schofield, William. Alma-road, Birkdale, Southport.
1885. §Scholes, L. Holly Bank, 19 Cleveland-road, Higher Crumpsall, near Manchester.
1888. ‡Scholey, J. Cranefield. 30 Sussex-villas, Kensington, London, W.
1887. ‡Schorlemmer, Carl, LL.D., F.R.S., Professor of Organic Chemistry in the Owens College, Manchester. Victoria Park, Manchester.
SCHUNCK, EDWARD, Ph.D., F.R.S., F.C.S. Oaklands, Kersal Moor, Manchester.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S., Professor of Physics in the Owens College, Manchester.
1861. *Schwabe, Edmund Salis. Ryecroft House, Cheetham Hill, Manchester.
1887. ‡Schwabe, Colonel G. Salis. Portland House, Higher Crumpsall, Manchester.
1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., Sec.Z.S. 3 Hanover-square, London, W.
1883. *SCLATER, WILLIAM LUTLEY, B.A., F.Z.S. 3 Hanover-square, London, W.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1881. *Scott, Alexander, M.A., D.Sc. 4 North Bailey, Durham.
1882. ‡Scott, Colonel A. de C., R.E. Ordnance Survey Office, Southampton.
1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1881. ‡Scott, Miss Charlotte Angus. Lancashire College, Whalley Range, Manchester.
1889. §SCOTT, D. H., M.A., Ph.D., F.L.S. The Laurels, Bickley, Kent.
1885. ‡Scott, George Jamieson. Bayview House, Aberdeen.

Year of Election.

1886. ‡Scott, Robert. 161 Queen Victoria-street, London, E.C.
1857. *Scott, Robert H., M.A., F.R.S., F.G.S., F.R.Met.S., Secretary to the Council of the Meteorological Office. 6 Elm Park-gardens, London, S.W.
1861. §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.
1884. *Scott, Sydney C. 15 Queen-street, Cheapside, London, E.C.
1869. ‡Scott, William Bower. Chudleigh, Devon.
1885. ‡*Scott-Moncrieff, W. G. The Castle, Banff.*
1881. *Scrivener, A. P. Haglis House, Wendover.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1890. §Searle, G. F. C., B.A. Peterhouse, Cambridge.
1859. ‡Seaton, John Love. The Park, Hull.
1880. ‡Sedgwick, Adam, M.A., F.R.S. Trinity College, Cambridge.
1880. ‡Seebohm, Henry, F.R.G.S., F.L.S., F.Z.S. 22 Courtfield-gardens, London, S.W.
1861. *Seeley, Harry Govier, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geography in King's College, London. 25 Palace Gardens-terrace, Kensington, London, W.
1855. ‡Seligman, H. L. 27 St. Vincent-place, Glasgow.
1879. §Selim, Adolphus. 21 Mincing-lane, London, E.C.
1885. §Semple, Dr. United Service Club, Edinburgh.
1887. §Semple, James C., M.R.I.A. 64 Grosvenor-road, Rathmines, Dublin.
1873. ‡Semple, R. H., M.D. 8 Torrington-square, London, W.C.
1888. §Senier, Alfred, M.D., Ph.D., F.C.S. Thornfield, Harold-road, London, S.E.
1858. *Senior, George, F.S.S. Old Whittington, Chesterfield.
1888. *Sennett, Alfred R., A.M.Inst.C.E. Temple-chambers, Victoria Embankment, London, E.C.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1883. ‡Seville, Miss M. A. Blythe House, Southport.
1875. ‡Seville, Thomas. Blythe House, Southport.
1868. ‡Sewell, Philip E. Catton, Norwich.
1888. §Shackles, Charles F. Hornsea, near Hull.
1883. ‡Shadwell, John Lancelot. 17 St. Charles-square, Ladbroke Grove-road, London, W.
1871. *Shand, James. Parkholme, Elm Park-gardens, London, S.W.
1867. ‡Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. ‡Shann, George, M.D. Petergate, York.
1869. *Shapter, Dr. Lewis, LL.D. 1 Barnfield-crescent, Exeter.
1878. ‡Sharp, David, M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1886. ‡Sharp, T. B. French Walls, Birmingham.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
1883. ‡Sharples, Charles H., F.C.S. 7 Fishergate, Preston.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1881. *Shaw, H. S. Hele, M.Inst.C.E., Professor of Engineering in University College, Liverpool.
1887. *Shaw, James B. Holly Bank, Cornbrook, Manchester.
1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1887. §Shaw, Saville. College of Science, Newcastle-upon-Tyne.
1883. *Shaw, W. N., M.A. Emmanuel House, Cambridge.
1883. ‡Shaw, Mrs. W. N. Emmanuel House, Cambridge.

Year of Election.

1883. ‡*Sheard, J. 42 Hoghton-street, Southport.*
1884. ‡Sheldon, Professor J. P. Downton College, near Salisbury.
1878. §Shelford, William, M.Inst.C.E. 35A Great George-street, Westminster, S.W.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1881. ‡SHENSTONE, W. A. Clifton College, Bristol.
1885. ‡Shepherd, Rev. Alexander. Ecclesmechen, Uphall, Edinburgh.
1863. ‡*Shepherd, A. B. 17 Great Cumberland-place, Hyde Park, London, W.*
1885. ‡Shepherd, Charles. 1 Wellington-street, Aberdeen.
1890. §Shepherd, J. Care of J. Redmayne, Esq., Grove House, Headingley, Leeds.
1883. ‡Shepherd, James. Birkdale, Southport.
1883. §Sherlock, David. Lower Leeson-street, Dublin.
1883. §Sherlock, Mrs. David. Lower Leeson-street, Dublin.
1883. ‡Sherlock, Rev. Edgar. Bentham Rectory, *viâ* Lancaster.
1888. *Shickle, Rev. C. W., M.A. Langridge Rectory, Bath.
1886. ‡Shield, Arthur H. 35A Great George-street, London, S.W.
1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, London, E.C.
1867. ‡Shinn, William C. 39 Varden's-road, Clapham Junction, Surrey, S.W.
1887. *SHIPLEY, ARTHUR E., M.A. Christ's College, Cambridge.
1889. ‡Shipley, J. A. D. Saltwell Park, Gateshead.
1885. ‡Shirras, G. F. 16 Carden-place, Aberdeen.
1883. ‡Shone, Isaac. Pentrefelin House, Wrexham.
1870. *SHOOLBRED, JAMES N., M.Inst.C.E., F.G.S. 1 Westminster-chambers, London, S.W.
1888. §Shoppee, C. H. 22 John-street, Bedford-row, London, W.C.
1888. §Shoppee, G. A., M.A., LL.D. 61 Doughty-street, London, W.C.
1875. ‡SHORE, THOMAS W., F.C.S., F.G.S. Hartley Institution, Southampton.
1882. ‡SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital. Sunny Bank, Church-lane, Hornsey, London, N.
1881. ‡*Shuter, James L. 9 Steele's-road, Haverstock Hill, London, N.W.*
1889. §Sibley, Walter K., B.A., M.B. 7 Harley-street, London, W.
1883. ‡Sibly, Miss Martha Agnes. Flook House, Taunton.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1883. *Sidebotham, James Nasmyth. Parkfield, Altrincham, Cheshire.
1877. *Sidebotham, Joseph Watson. Erlesdene, Bowdon, Cheshire.
1885. *SIDGWICK, HENRY, M.A., Litt.D., D.C.L., Professor of Moral Philosophy in the University of Cambridge. Hillside, Chesterton-road, Cambridge.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 7 Airlie-gardens, Campden Hill, London, W.
1878. ‡SIGERSON, Professor GEORGE, M.D., F.L.S., M.R.I.A. 3 Clare-street, Dublin.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1874. ‡Simms, William. The Linen Hall, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, London, W.
1887. *Simon, Henry. Darwin House, Didsbury, near Manchester.
1847. ‡Simon, Sir John, K.C.B., D.C.L., F.R.S., F.R.C.S., Consulting Surgeon to St. Thomas's Hospital. 40 Kensington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.

Year of Election.

1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1883. ‡Simpson, Byron R. 7 York-road, Birkdale, Southport.
1887. ‡Simpson, F. Estacion Central, Buenos Ayres.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Maykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., LL.D., F.R.S., F.C.S., Professor of Chemistry in Queen's College, Cork.
1883. ‡Simpson, Walter M. 7 York-road, Birkdale, Southport.
Simpson, William. Bradmore House, Hammersmith, London, W.
1887. ‡Sinclair, Dr. 268 Oxford-street, Manchester.
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1870. *Sinclair, W. P., M.P. Rivelyn, Prince's Park, Liverpool.
1864. *Sircar, The Hon. Mahendra Lal, M.D., C.I.E. 51 Sankaritola, Calcutta.
1865. ‡Sissons, William. 92 Park-street, Hull.
1879. ‡Skertchly, Sydney B. J., F.G.S. 3 Loughborough-terrace, Carshalton, Surrey.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1885. ‡Skinner, Provost. Inverurie, N.B.
1888. ‡SKRINE, H. D., J.P., D.L. Claverton Manor, Bath.
1870. §SLADEN, WALTER PERCY, F.G.S., F.L.S. Orsett House, Ewell, Surrey.
1873. ‡Slater, Clayton. Barnoldswick, near Leeds.
1889. §Slater, Matthew B., F.L.S. Malton, Yorkshire.
1884. ‡Slattery, James W. 9 Stephen's-green, Dublin.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S., F.G.S. Clifton, Bristol.
1884. ‡Slooten, William Venn. Nova Scotia, Canada.
1849. ‡Sloper, George Elgar. Devizes.
1860. ‡Sloper, S. Elgar. Winterton, near Hythe, Southampton.
1867. ‡Small, David. Gray House, Dundee.
1887. §Small, E. W. 11 Arthur-street, Nottingham.
1887. §Small, William. Cavendish-crescent North, The Park, Nottingham.
1881. ‡Smallshan, John. 81 Manchester-road, Southport.
1885. §Smart, James. Valley Works, Brechin, N.B.
1889. *Smart, William. Nunholme, Dowanhill, Glasgow.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1876. §Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1890. §Smethurst, Charles. Palace House, Harpurhey, Manchester.
1876. ‡Smieton, James. Panmure Villa, Broughty Ferry, Dundee.
1876. ‡Smieton, John G. 3 Polworth-road, Coventry Park, Streatham, London, S.W.
1867. ‡Smieton, Thomas A. Panmure Villa, Broughty Ferry, Dundee.
1857. ‡Smith, Aquilla, M.D., M.R.I.A. 121 Lower Baggot-street, Dublin.
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead Heath, London, N.W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, London, S.W.
1887. ‡Smith, Bryce. Rye Bank, Chorlton-cum-Hardy, Manchester.
1873. ‡Smith, C. Sidney College, Cambridge.
1887. *Smith, Charles. 739 Rochdale-road, Manchester.
1889. *Smith, C. Michie, B.Sc., F.R.S.E., F.R.A.S. Madras.
1865. ‡SMITH, DAVID, F.R.A.S. 40 Bennett's-hill, Birmingham.
1886. ‡Smith, Edwin. 33 Wheeley's-road, Edgbaston, Birmingham.

Year of Election.

1886. ‡Smith, E. Fisher, J.P. The Priory, Dudley.
1886. ‡Smith, E. O. Council House, Birmingham.
1866. *Smith, F. C. Bank, Nottingham.
1887. §Smith, Rev. F. J., M.A. Trinity College, Oxford.
1855. ‡*Smith, George. Port Dundas, Glasgow.*
1885. ‡Smith, Rev. G. A., M.A. 91 Fountainhall-road, Aberdeen.
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, London, W.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1889. *Smith, H. Llewellyn, B.A., B.Sc., F.S.S. 49 Beaumont-square, London, E.
1888. ‡Smith, H. W. Owens College, Manchester.
1885. ‡Smith, Rev. James, B.D. Manse of Newhills, N.B.
1876. *Smith, J. Guthrie. 54 West Nile-street, Glasgow.
1874. ‡*Smith, John Haigh. 77 Southbank-road, Southport.*
Smith, John Peter George. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1871. ‡Smith, J. William Robertson, M.A., Lord Almoner's Professor of Arabic in the University of Cambridge.
1883. ‡Smith, M. Holroyd. Fern Hill, Halifax.
1886. *Smith, Mrs. Hencotes House, Hexham.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1885. ‡SMITH, ROBERT H., M.Inst.C.E., Professor of Engineering in the Mason Science College, Birmingham.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. ‡Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1873. ‡Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hornsea Burton, East Yorkshire.
1884. ‡Smith, Vernon. 127 Metcalfe-street, Ottawa, Canada.
1885. *Smith, Watson. University College, London, W.C.
1887. §Smith, Dr. Wilberforce. 14 Stratford-place, London, W.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton, Bristol.
1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1883. ‡SMITHELLS, ARTHUR, B.Sc., Professor of Chemistry in the Yorkshire College, Leeds.
1883. ‡Smithson, Edward Walter. 13 Lendal, York.
1883. ‡Smithson, Mrs. 13 Lendal, York.
1878. ‡Smithson, Joseph S. Balnagowan, Rathmines, Co. Dublin.
1882. §Smithson, T. Spencer. Facit, Rochdale.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1850. *SMYTH, CHARLES PIAZZI, F.R.S.E., F.R.A.S. Clova, Ripon.
1883. ‡Smyth, Rev. Christopher. The Vicarage, Bussage, Stroud.
1874. ‡Smyth, Henry. Downpatrick, Ireland.
1878. §Smyth, Mrs. Isabella. Wigmore Lodge, Cullenswood-avenue, Dublin.
1857. *SMYTH, JOHN, jun., M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1888. *SNAPE, H. LLOYD, D.Sc., Ph.D., F.C.S., Professor of Chemistry in University College, Aberystwith.
1888. ‡Snell, Albion T. Messrs. Immisch & Co., London.
1887. ‡Snell, Rev. Bernard J., M.A. 5 Park-place, Broughton, Manchester.
1878. ‡Snell, H. Saxon. 22 Southampton-buildings, London, W.C.
1889. ‡Snell, W. H. Lamorna, Oxford-road, Putney, S.W.

Year of Election.

1879. *SOLLAS, W. J., M.A., D.Sc., F.R.S., F.R.S.E., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *SORBY, H. CLIFTON, LL.D., F.R.S., F.G.S. Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Sheffield.
1888. ‡Sorley, Professor W. R. University College, Cardiff.
1886. ‡Southall, Alfred. Carrick House, Richmond Hill-road, Birmingham.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1887. §Sowerbutts, Eli, F.R.G.S. Market-place, Manchester.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1890. §Spark, F. R. 29 Hyde-terrace, Leeds.
1863. *Spark, H. King, F.G.S. Startforth House, Barnard Castle.
1889. ‡Spence, Faraday. 67 Grey-street, Hexham.
1869. *Spence, J. Berger. 31 Lombard-street, London, E.C.
1887. §Spencer, F. M. Fernhill, Knutsford.
1881. ‡*Spencer, Herbert E. Lord Mayor's Walk, York.*
1884. §Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1889. *Spencer, John. Newburn, Newcastle-upon-Tyne.
1861. ‡*Spencer, John Frederick. 28 Great George-street, London, S.W.*
1861. **Spencer, Joseph. Springbank, Old Trafford, Manchester.*
1891. *Spencer, Richard Evans. 6 Working-street, Cardiff.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1875. ‡*Spencer, W. H. Richmond Hill, Clifton, Bristol.*
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, London, N.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, London, N.
1878. §Spottiswoode, George Andrew. 3 Cadogan-square, London, S.W.
1864. *Spottiswoode, W. Hugh, F.C.S. 41 Grosvenor-place, London, S.W.
1854. *SPRAGUE, THOMAS BOND, M.A., F.R.S.E. 26 St. Andrew-square, Edinburgh.
1883. ‡Spratling, W. J., B.Sc., F.G.S. Maythorpe, 74 Wickham-road, Brockley, S.E.
1853. ‡*Spratt, Joseph James. West-parade, Hull.*
1888. ‡Spreat, John Henry. Care of Messrs. Vines & Froom, 75 Aldersgate-street, London, E.C.
1884. *Spruce, Samuel. Beech House, Tamworth.
Square, Joseph Elliot. 147 Maida Vale, London, W.
1877. ‡SQUARE, WILLIAM, F.R.C.S., F.R.G.S. 4 Portland-square, Plymouth.
*Squire, Lovell. 6 Heathfield-terrace, Chiswick, Middlesex.
1890. §Stables, James. Lane Ends, Horsham.
1888. *Stacy, J. Sargeant. 7 and 8 Paternoster-row, London, E.C.
1858. *STAINTON, HENRY T., F.R.S., F.L.S., F.G.S. Mountsfield, Lewisham, S.E.
1884. ‡Stancoffe, Frederick. Dorchester-street, Montreal, Canada.
1883. *Stanford, Edward, jun., F.R.G.S. Thornbury, Bromley, Kent.
1865. ‡STANFORD, EDWARD C. C., F.C.S. Glenwood, Dalmuir, N.B.
1881. *Stanley, William Ford, F.G.S. Cumberlow, South Norwood, Surrey, S.E.
1883. ‡Stanley, Mrs. Cumberlow, South Norwood, Surrey, S.E.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1883. ‡Stapley, Alfred M. Marion-terrace, Crewe.
1876. ‡Starling, John Henry, F.C.S. The Avenue, Erith, Kent.
Staveley, T. K. Ripon, Yorkshire.

Year of Election.

1873. *Stead, Charles. Saltaire, Bradford, Yorkshire.
1881. ‡Stead, W. H. Orchard-place, Blackwall, London, E.
1881. ‡Stead, Mrs. W. H. Orchard-place, Blackwall, London, E.
1884. ‡Stearns, Sergeant P. U.S. Consul-General, Montreal, Canada.
1873. ‡Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1887. ‡Steinthal, Rev. S. Alfred. 81 Nelson-street, Manchester.
1887. ‡Stelfox, John L. 6 Hilton-street, Oldham, Manchester.
1884. ‡Stephen, George. 140 Drummond-street, Montreal, Canada.
1884. ‡Stephen, Mrs. George. 140 Drummond-street, Montreal, Canada.
1884. *Stephens, W. Hudson. Lowville (P.O.), State of New York, U.S.A.
1879. *STEPHENSON, Sir HENRY, J.P. The Glen, Sheffield.
1870. *Stevens, Miss Anna Maria. 23 Elm Grove-terrace, London-road, Salisbury.
1880. *Stevens, J. Edward. 16 Woodlands-terrace, Swansea.
1886. ‡Stevens, Marshall. Highfield House, Urmston, near Manchester.
1878. ‡*Stevenson, Rev. James, M.A. 21 Garville-avenue, Rathgar, Dublin.*
1863. *STEVENSON, JAMES C., M.P., F.C.S. Westoe, South Shields.
1889. ‡Stevenson, T. Shannon. Westoe, South Shields.
1882. ‡*Steward, Rev. C. E., M.A. The Polygon, Southampton.*
1890. *Steward, Rev. Charles J., F.R.M.S. Somerleyton Rectory, Lowestoft.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Heathcot, Aberdeen.
1864. ‡STEWART, CHARLES, M.A., F.L.S. St. Thomas's Hospital, London, S.E.
1885. ‡Stewart, David. Banchory House, Aberdeen.
1886. *Stewart, Duncan. 12 Montgomerie-crescent, Kelvinside, Glasgow.
1887. ‡Stewart, George N. Physiological Laboratory, Owens College, Manchester.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Owens College, Manchester.
1867. *Stirrup, Mark, F.G.S. Stamford-road, Bowdon, Cheshire.
1865. *Stock, Joseph S. St. Mildred's, Walmer.
1890. §Stockdale, R. The Grammar School, Leeds.
1883. *STOCKER, W. R. Cooper's Hill, Staines.
1854. ‡Stoess, Le Chevalier Ch. de W. (Bavarian Consul). Liverpool.
1845. *STOKES, Sir GEORGE GABRIEL, Bart., M.P., M.A., D.C.L., LL.D., D.Sc., F.R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1887. ‡Stone, E. D., F.C.S. The Depleach, Cheadle, Cheshire.
1862. ‡STONE, EDWARD JAMES, M.A., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1886. ‡Stone, J. B. The Grange, Erdington, Birmingham.
1886. ‡Stone, J. H. Grosvenor-road, Handsworth, Birmingham.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 11 Sheffield-gardens, Kensington, London, W.
1888. ‡STONE, JOHN. 15 Royal-crescent, Bath.
1876. ‡*Stone, Octavius C., F.R.G.S. Springfield, Nuneaton.*
1883. ‡Stone, Thomas William. 189 Goldhawk-road, Shepherd's Bush, London, W.
1859. ‡STONE, Dr. WILLIAM H. 14 Dean's-yard, Westminster, S.W.
1857. ‡STONEY, BINDON B., LL.D., F.R.S., M.Inst.C.E., M.R.I.A., Engineer of the Port of Dublin. 14 Elgin-road, Dublin.
1878. *Stoney, G. Gerald. 9 Palmerston Park, Dublin.

Year of Election.

1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. 9 Palmerston Park, Dublin.
1876. §Stopes, Henry, F.G.S. Kenwyn, Cintra Park, Upper Norwood, S.E.
1883. §Stopes, Mrs. Kenwyn, Cintra Park, Upper Norwood, S.E.
1887. ‡Storer, Edwin. Woodlands, Crumpsall, Manchester.
1887. *Storey, H. L. Caton, near Lancaster.
1873. ‡Storr, William. The 'Times' Office, Printing-house-square, London, E.C.
1884. §Storrs, George H. Fern Bank, Stalybridge.
1859. §Story, Captain James Hamilton. 17 Bryanston-square, London, W.
1888. ‡STOTHERT, J. L., M.Inst.C.E. Audley, Park-gardens, Bath.
1888. *Stothert, Percy K. Audley, Park-gardens, Bath.
1874. ‡Stott, William. Scar Bottom, Greetland, near Halifax, Yorkshire.
1871. *STRACHEY, Lieut.-General RICHARD, R.E., C.S.I., F.R.S., F.R.G,S., F.L.S., F.G.S. 69 Lancaster-gate, Hyde Park, London, W.
1881. ‡Strahan, Aubrey, M.A., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1876. ‡Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.
1889. §Straker, Captain Joseph. Dilston House, Riding Mill-on-Tyne.
1882. ‡Strange, Rev. Cresswell, M.A. Edgbaston Vicarage, Birmingham.
1881. ‡Strangways, C. Fox, F.G.S. Geological Museum, Jermyn-street, London, S.W.
1889. §Streatfield, H. S. The Limes, Leigham Court-road, Streatham, S.W.
*Strickland, Charles. 21 Fitzwilliam-place, Dublin.
1879. ‡Strickland, Sir Charles W., K.C.B. Hildenley-road, Malton.
1884. ‡Stringham, Irving. The University, Berkeley, California, U.S.A.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1883. §Strong, Henry J., M.D. Whitgift House, Croydon.
1867. ‡Stronner, D. 14 Princess-street, Dundee.
1887. *Stroud, Professor H., M.A., D.Sc., College of Science, Newcastle-upon-Tyne.
1887. *Stroud, William, D.Sc., Professor of Physics in the Yorkshire College, Leeds.
1876. *STRUTHERS, JOHN, M.D., LL.D. Aberdeen.
1878. ‡Strype, W. G. Wicklow.
1876. *Stuart, Charles Maddock. High School, Newcastle, Staffordshire.
1872. *Stuart, Rev. Edward A., M.A. 116 Grosvenor-road, Highbury New Park, London, N.
1886. ‡Stuart, G. Morton, M.A. East Harptree, near Bristol.
1884. ‡Stuart, Dr. W. Theophilus. 183 Spadina-avenue, Toronto, Canada.
1888. *Stubbs, Rev. Elias T., M.A. 4 Springfield-place, Bath.
1885. §Stump, Edward C. 26 Parkfield-street, Moss-lane East, Manchester.
1879. *Styring, Robert. 3 Hartshead, Sheffield.
Sulivan, H. N., F.R.G.S. King-street, Newcastle-upon-Tyne.
1883. ‡Summers, William, M.P. Sunnyside, Ashton-under-Lyne.
1884. ‡Sumner, George. 107 Stanley-street, Montreal, Canada.
1887. ‡Sumpner, W. E. 37 Pennyfields, Poplar, London, E.
1888. ‡Sunderland, John E. Bark House, Hatherlow, Stockport.
1883. ‡Sutcliffe, J. S., J.P. Beech House, Bacup.
1873. ‡Sutcliffe, J. W. Sprink Bank, Bradford, Yorkshire.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. Thurso House, Newcastle-upon-Tyne.
1862. *SUTHERLAND, GEORGE GRANVILLE WILLIAM, Duke of, K.G., F.R.S., F.R.G.S. Stafford House, London, S.W.
1886. ‡Sutherland, Hugh. Winnipeg, Manitoba, Canada.

Year of Election.

1884. ‡Sutherland, J. C. Richmond, Quebec, Canada.
1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1881. ‡Sutton, William. Town Hall, Southport.
1889. ‡Sutton, William. Esbank, Jesmond, Newcastle-upon-Tyne.
1881. ‡Swales, William. Ashville, Holgate Hill, York.
1876. ‡Swan, David, jun. Braeside, Maryhill, Glasgow.
1881. ‡Swan, Joseph Wilson, M.A. Lauriston, Bromley, Kent.
1861. *Swan, Patrick Don S. Kirkcaldy, N.B.
1862. *SWAN, WILLIAM, LL.D., F.R.S.E., Emeritus Professor of Natural Philosophy in the University of St. Andrews. Ardchapel, Helensburgh, N.B.
1879. ‡Swanwick, Frederick. Whittington, Chesterfield.
1883. ‡Sweeting, Rev. T. E. 50 Roe-lane, Southport.
1887. §Swinburne, James. 49 Queen's-road, Wimbledon, Surrey.
1870. *Swinburne, Sir John, Bart., M.P. Capheaton, Newcastle-upon-Tyne.
1885. ‡Swindells, Miss. Springfield House, Ilkley, Yorkshire.
1887. *Swindells, Rupert, F.R.G.S. Wilton Villa, The Firs, Bowdon, Cheshire.
1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1890. §Swinhoe, Colonel C. Avenue House, Oxford.
1889. §Sworn, Sidney A., B.A., F.C.S. 152 Railton-road, Herne Hill, London, S.E.
1883. ‡Sykes, Alfred. Highfield, Huddersfield.
1873. §Sykes, Benjamin Clifford, M.D. St. John's House, Cleckheaton.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. 12 Albert-square, Clapham, London, S.W.
1890. §Sykes, Joseph. 113 Beeston-hill, Leeds.
1862. ‡*Sykes, Thomas. Cleckheaton.*
1887. *Sykes, T. H. Cheadle, Cheshire.
SYLVESTER, JAMES JOSEPH, M.A., D.C.L., LL.D., F.R.S., Savilian Professor of Geometry in the University of Oxford. Oxford.
1870. ‡SYMES, RICHARD GLASCOTT, B.A., F.G.S., Geological Survey of Ireland. 14 Hume-street, Dublin.
1885. ‡Symington, Johnson, M.D. 2 Greenhill Park, Edinburgh.
1881. *Symington, Thomas. Wardie House, Edinburgh.
1859. §SYMONS, G. J., F.R.S., Sec.R.Met.Soc. 62 Camden-square, London, N.W.
1883. ‡*Symons, Simon. Belfast House, Farquhar-road, Norwood, S.E.*
1855. *SYMONS, WILLIAM, F.C.S. Dragon House, Bilbrook, near Taunton.
1886. §Symons, W. H., F.I.C., F.R.M.S. 130 Fellowes-road, Hampstead, London, N.W.
1872. ‡Synge, Major-General Millington, R.E., F.S.A., F.R.G.S. United Service Club, Pall Mall, London, S.W.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.
1877. *TAIT, LAWSON, F.R.C.S. The Crescent, Birmingham.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1867. ‡Tait, P. M., F.R.G.S., F.S.S. Hardwicke House, Hardwicke-road, Eastbourne.
1890. §Talbot, Rev. E. S. The Vicarage, Leeds.
1890. §TANNER, H. W. LLOYD, M.A., Professor of Mathematics and Astronomy in University College, Cardiff.
1883. §Tapscott, R. L., F.G.S. 62 Croxteth-road, Liverpool.
1878. ‡TARPEY, HUGH. Dublin.
1861. *Tarratt, Henry W. Moseley, Owl's-road, Boscombe, Bournemouth.
1857. *Tate, Alexander. Longwood, Whitehouse, Belfast.

Year of
Electio .

1870. ‡Tate, A. Norman, F.C.S. 9 Hackins Hey, Liverpool.
1890. §Tate, Thomas, F.G.S. 5 Eldon-mount, Woodhouse-lane, Leeds.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1886. ‡Taunton, Richard. Brook Vale, Witton.
1878. *Taylor, A. Claude. North Circus-street, Nottingham.
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
Taylor, Frederick. Laurel Cottage, Rainhill, near Prescot, Lancashire.
1887. §Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1887. §Taylor, George Spratt, F.C.S. 13 Queen's-terrace, St. John's Wood, London, N.W.
1881. *Taylor, H. A. 25 Collingham-road, South Kensington, London, S.W.
1884. *Taylor, H. M., M.A. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. 17 Castlegate, Nottingham.
1887. ‡TAYLOR, Rev. Canon ISAAC, D.D. Settrington Rectory, York.
1879. ‡Taylor, John. Broomhall-place, Sheffield.
1861. *Taylor, John, M.Inst.C.E., F.G.S. 29 Portman-square, London, W.
1873. ‡TAYLOR, JOHN ELLOR, Ph.D., F.L.S., F.G.S. The Mount, Ipswich.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1883. ‡Taylor, Michael W., M.D. Hatton Hall, Penrith.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1878. ‡*Taylor, Robert, J.P., LL.D. Corballis, Drogheda.*
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1881. ‡Taylor, Rev. S. B., M.A. Whixley Hall, York.
1883. ‡Taylor, S. Leigh. Birklands, Westcliffe-road, Birkdale, Southport.
1870. ‡Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
1887. ‡Taylor, Tom. Grove House, Sale, Manchester.
1883. ‡Taylor, William, M.D. 21 Crockherbtown, Cardiff.
1884. ‡Taylor-Whitehead, Samuel, J.P. Burton Closes, Bakewell.
1858. ‡Teale, Thomas Pridgin, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡Teall, J. J. H., M.A., F.R.S., F.G.S. 28 Jermyn-street, London, S.W.
1869. ‡*Teesdale, C. S. M. Whyke House, Chichester.*
1879. ‡Temple, Lieutenant George T., R.N., F.R.G.S. The Nash, near Worcester.
1880. §TEMPLE, Sir RICHARD, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., M.P., F.R.G.S. Athenæum Club, London, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
1889. §Tennant, James. Dartmoor Lodge, Gateshead.
1882. §Terrill, William. 42 St. George's-terrace, Swansea.
1881. ‡Terry, Mr. Alderman. Mount-villas, York.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1887. ‡Tetlow, T. 273 Stamford-street, Ashton-under-Lyne.
1882. *Thane, George Dancer, Professor of Anatomy in University College, Gower-street, London, W.C.
1885. ‡Thin, Dr. George, 22 Queen Anne-street, London, W.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡THISELTON-DYER, W. T., C.M.G., M.A., B.Sc., F.R.S., F.L.S. Royal Gardens, Kew.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.

Year of Election.

1875. *THOMAS, CHRISTOPHER JAMES. Drayton Lodge, Redland, Bristol.
1883. ‡Thomas, Ernest C., B.A. 13 South-square, Gray's Inn, London, W.C.
1884. ‡THOMAS, F. WOLFERSTAN. Molson's Bank, Montreal, Canada.
Thomas, George. Brislington, Bristol.
1875. ‡Thomas, Herbert. Ivor House, Redland, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1881. §THOMAS, J. BLOUNT. Southampton.
1869. ‡Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
1880. *Thomas, Joseph William, F.C.S. The Laboratory, West Wharf, Cardiff.
1883. ‡Thomas, P. Bossley. 4 Bold-street, Southport.
1883. §Thomas, Thomas H. 45 The Walk, Cardiff.
1883. ‡Thomas, William. Lan, Swansea.
1886. ‡Thomas, William. 109 Tettenhall-road, Wolverhampton.
1886. §Thomasson, Yeoville. 9 Observatory-gardens, Kensington, London, W.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1887. §Thompson, C. 15 Patshull-road, Kentish Town, London, N.W.
1883. ‡Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1882. ‡Thompson, Charles O. Terre Haute, Indiana, U.S.A.
1888. *Thompson, Claude M., M.A., Professor of Chemistry in University College, Cardiff.
1885. ‡Thompson, D'Arcy W., B.A., Professor of Physiology in University College, Dundee. University College, Dundee.
1883. *Thompson, Francis. Lynton, Haling Park-road, Croydon.
1859. ‡Thompson, George, jun. Pitmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, London, W.
1889. ‡Thompson, Henry. 2 Eslington-terrace, Newcastle-upon-Tyne.
1883. *Thompson, Henry G., M.D. 8 Addiscombe-villas, Croydon.
Thompson, Henry Stafford. Fairfield, near York.
1883. *THOMPSON, ISAAC COOKE, F.L.S., F.R.M.S. Woodstock, Waverley-road, Liverpool.
1861. *THOMPSON, JOSEPH. Riversdale, Wilmslow, Manchester.
1873. ‡Thompson, Sir M. W., Bart. Guiseley, Yorkshire.
1876. *Thompson, Richard. Hob Moor, York.
1883. ‡Thompson, Richard. Bramley Mead, Whalley, Lancashire.
1874. ‡Thompson, Robert. Walton, Fortwilliam Park, Belfast.
1876. ‡THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.A.S., Professor of Physics in the City and Guilds of London Institute, Finsbury Technical Institute, E.C.
1884. ‡*Thompson, Sydney de Courcy.* 16 *Canonbury-park South, London, N.*
1883. *Thompson, T. H. Heald Bank, Bowdon, Manchester.
1863. ‡*Thompson, William.* 11 *North-terrace, Newcastle-upon-Tyne.*
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1850. *THOMSON, JAMES, M.A., LL.D., D.Sc., F.R.S. L. & E. 2 Florentine-gardens, Hillhead-street, Glasgow.
1889. *Thomson, James, jun., M.A. 2 Florentine-gardens, Hillhead-street, Glasgow.
1868. §THOMSON, JAMES, F.G.S. 26 Leven-street, Pollokshields, Glasgow.
1876. ‡Thomson, James R. Mount Blow, Dalmuir, Glasgow.
1890. §Thomson, J. Arthur. 30 Royal-circus, Edinburgh.
1883. ‡THOMSON, J. J., M.A., F.R.S., Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1871. *THOMSON, JOHN MILLAR, F.C.S., Professor of Chemistry in King's College, London. 53 Prince's-square, London, W.
1886. ‡Thomson, Joseph. Thornhill, Dumfries-shire.

Year of Election.

1863. ‡Thomson, Murray. 44 Victoria-road, Gipsy Hill, London, S.E.
1847. *THOMSON, Sir WILLIAM, M.A., LL.D., D.C.L., Pres.R.S., F.R.S.E., F.R.A.S., Professor of Natural Philosophy in the University of Glasgow. The University, Glasgow.
1877. *Thomson, Lady. The University, Glasgow.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1852. ‡Thornburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
1886. §Thornley, J. E. Lyndon, Bickenhill, near Birmingham.
1887. ‡Thornton, John. 3 Park-street, Bolton.
1867. ‡Thornton, Thomas. Dundee.
1883. §Thorowgood, Samuel. Castle-square, Brighton.
1845. ‡Thorp, Dr. Disney. Lypiatt Lodge, Suffolk Lawn, Cheltenham.
1881. ‡Thorp, Fielden. Blossom-street, York.
1871. ‡Thorp, Henry. Briarleigh, Sale, near Manchester.
1881. *Thorp, Josiah. 86 Canning-street, Liverpool.
1864. *Thorp, William, B.Sc., F.C.S. 24 Crouch Hall-road, Crouch End, London, N.
1871. ‡THORPE, T. E., Ph.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in the Royal College of Science, South Kensington, London, S.W.
1883. §Threlfall, Henry Singleton. 12 London-street, Southport.
1883. ‡Thresh, John C., D.Sc. The Willows, Buxton.
1868. ‡THUILLIER, General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S. Tudor House, Richmond Green, Surrey.
1889. ‡Thys, Captain Albert. 9 Rue Briderode, Brussels.
1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.
1873. *TIDDEMAN, R. H., M.A., F.G.S. 28 Jermyn-street, London, S.W.
1885. §TIDY, CHARLES MEYMOTT, M.D. 3 Mandeville-place, Cavendish-square, London, W.
1874. ‡TILDEN, WILLIAM A., D.Sc., F.R.S., F.C.S., Professor of Chemistry and Metallurgy in the Mason Science College, Birmingham.
1873. ‡Tilghman, B. C. Philadelphia, U.S.A.
1883. ‡Tillyard, A. I., M.A. Fordfield, Cambridge.
1883. ‡Tillyard, Mrs. Fordfield, Cambridge.
1865. ‡Timmins, Samuel, J.P., F.S.A. Hill Cottage, Fillongley, Coventry.
1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, London, S.E.
1889. §Toll, John M. Monkton Lodge, Anfield, Liverpool.
1887. ‡Tolmé, Mrs. Melrose House, Higher Broughton, Manchester.
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1888. ‡Tomkins, Rev. Henry George. Park Lodge, Weston-super-Mare.
1864. *TOMLINSON, CHARLES, F.R.S., F.C.S. 7 North-road, Highgate, London, N.
1887. ‡Tonge, Rev. Canon. Chorlton-cum-Hardy, Manchester.
1887. ‡Tonge, James. Woodbine House, West Houghton, Bolton.
1865. ‡Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1865. *Tonks, William Henry. The Rookery, Sutton Coldfield.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.
1887. ‡Topham, F. 15 Great George-street, London, S.W.
1861. *Topham, John, A.I.C.E. High Elms, 265 Mare-street, Hackney, London, E.
1872. *TOPLEY, WILLIAM, F.R.S., F.G.S., A.I.C.E. Geological Survey Office, Jermyn-street, London, S.W.
1886. ‡Topley, Mrs. W. Hurstbourne, Elgin-road, Croydon.

Year of Election.

1875. §Torr, Charles Hawley. St. Alban's Tower, Mansfield-road, Sherwood, Nottingham.
1886. ‡Torr, Charles Walker. Cambridge-street Works, Birmingham.
1884. ‡Torrance, John F. Folly Lake, Nova Scotia, Canada.
1884. *Torrance, Rev. Robert, D.D. Guelph, Ontario, Canada.
Towgood, Edward. St. Neot's, Huntingdonshire.
1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875. ‡Townsend, Charles. Avenue House, Cotham Park, Bristol.
1883. ‡*Townsend, Francis Edward.* 19 *Aughton-road, Birkdale, Southport.*
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1877. ‡Tozer, Henry. Ashburton.
1876. *TRAIL, Professor J. W. H., M.A., M.D., F.L.S. University of Aberdeen, Old Aberdeen.
1883. ‡TRAILL, A., M.D., LL.D. Ballylough, Bushmills, Ireland.
1870. ‡TRAILL, WILLIAM A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1875. ‡Trapnell, Caleb. Severnleigh, Stoke Bishop.
1868. ‡TRAQUAIR, RAMSAY H., M.D., F.R.S., F.G.S., Keeper of the Natural History Collections, Museum of Science and Art, Edinburgh.
1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
Trench, F. A. Newlands House, Clondalkin, Ireland.
1883. ‡Trendell, Edwin James, J.P. Abbey House, Abingdon, Berks.
1884. ‡Trenham, Norman W. 18 St. Alexis-street, Montreal, Canada.
1884. §Tribe, Paul C. M. 44 West Oneida-street, Oswego, New York, U.S.A.
1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.
1877. ‡TRIMEN, HENRY, M.B., F.R.S., F.L.S. Peradeniya, Ceylon.
1871. ‡TRIMEN, ROLAND, F.R.S., F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1860. §TRISTRAM, Rev. HENRY BAKER, D.D., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.
1884. *Trotter, Alexander Pelham. 53 Addison-mansions, Blythe-road, West Kensington, London, W.
1885. §TROTTER, COUTTS, F.G.S., F.R.G.S. 17 Charlotte-square, Edinburgh.
1887. *Trouton, Frederick T. Trinity College, Dublin.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1885. *Tubby, A. H. Guy's Hospital, London, S.E.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1888. ‡Tuckett, William Fothergill, M.D. 18 Daniel-street, Bath.
Tuke, James H. Bancroft, Hitchin.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1887. ‡Tuke, W. C. 29 Princess-street, Manchester.
1883. ‡TUPPER, The Hon. Sir CHARLES, Bart., G.C.M.G., C.B., High Commissioner for Canada. 9 Victoria-chambers, London, S.W.
1855. ‡Turnbull, John. 37 West George-street, Glasgow.
1871. ‡Turnbull, William, F.R.S.E. Menslaws, Jedburgh, N.B.
1882. ‡Turner, G. S. 9 Carlton-crescent, Southampton.
1883. ‡Turner, Mrs. G. S. 9 Carlton-crescent, Southampton.
1888. ‡Turner, J. S., J.P. Granville, Lansdowne, Bath.
1886. *TURNER, THOMAS, A.R.S.M., F.C.S., F.I.C. Mason Science College, Birmingham.
1863. *TURNER, Sir WILLIAM, M.B., LL.D., D.C.L., F.R.S. L. & E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1890. §Turpin, G. S., B.A. 2 St. James's-terrace, Nottingham.
1883. ‡Turrell, Miss S. S. High School, Redland-grove, Bristol.

Year of Election.

1884. *Tutin, Thomas. The Orchard, Chellaston, Derby.
1884. *Tweddell, Ralph Hart. Meopham Court, Gravesend, Kent.
1886. *Twigg, G. H. Church-road, Moseley, Birmingham.
1847. ‡Twiss, Sir Travers, Q.C., D.C.L., F.R.S., F.R.G.S. 3 Paper-buildings, Temple, London, E.C.
1888. §Tyack, Llewellyn Newton. University College, Bristol.
1882. §Tyer, Edward. Horneck, Fitzjohn's-avenue, Hampstead, London, N.W.
1865. §Tylor, Edward Burnett, D.C.L., LL.D., F.R.S., Keeper of the University Museum, Oxford.
1858. *Tyndall, John, D.C.L., LL.D., Ph.D., F.R.S., F.G.S., Hon. Professor of Natural Philosophy in the Royal Institution, London. Hind Head House, Haslemere, Surrey.
1883. ‡Tyrer, Thomas, F.C.S. Garden-wharf, Battersea, London, S.W.
1861. *Tysoe, John. 28 Heald-road, Bowdon, near Manchester.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1888. ‡Underhill, H. M. 7 High-street, Oxford.
1886. ‡Underhill, Thomas, M.D. West Bromwich.
1885. §Unwin, Howard. Newton-grove, Bedford Park, Chiswick, London.
1883. §Unwin, John. Park-crescent, Southport.
1883. §Unwin, William Andrews. The Briars, Freshfield, near Liverpool.
1876. *Unwin, W. C., F.R.S., M.Inst.C.E., Professor of Engineering at the Central Institute, City and Guilds of London. 7 Palace-gate Mansions, Kensington, London, W.
1887. ‡Upton, Francis R. Orange, New Jersey, U.S.A.
1872. ‡Upward, Alfred. 11 Great Queen-street, Westminster, London, S.W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.
1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1880. ‡Ussher, W. A. E., F.G.S. 28 Jermyn-street, London, S.W.

1885. ‡Vachell, Charles Tanfield, M.D. Cardiff.
1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1888. ‡Vallentin, Rupert. 18 Kimberley-road, Falmouth.
1884. ‡Van Horne, W. C. Dorchester-street West, Montreal, Canada.
1883. *VanSittart, The Hon. Mrs. A. A. 11 Lypiatt-terrace, Cheltenham.
1886. ‡Vardy, Rev. A. R., M.A. King Edward's School, Birmingham.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, London, N.
1865. *Varley, S. Alfred. 2 Hamilton-road, Highbury Park, London, N.
1870. ‡Varley, Mrs. S. A. 2 Hamilton-road, Highbury Park, London, N.
1869. ‡Varwell, P. Alphington-street, Exeter.
1884. ‡Vasey, Charles. 112 Cambridge-gardens, London, W.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. ‡Vaughan, William. 42 Sussex-road, Southport.
1881. §Veley, V. H., M.A., F.C.S. University College, Oxford.
1873. *Verney, Captain Edmund H., R.N., F.R.G.S. Rhianva, Bangor, North Wales.
1883. *Verney, Mrs. Rhianva, Bangor, North Wales.
Verney, Sir Harry, Bart., M.P. Lower Claydon, Buckinghamshire.
Vernon, George John, Lord. Sudbury Hall, Derbyshire.
1883. ‡Vernon, H. H., M.D. York-road, Birkdale, Southport.
1864. *Vicary, William, F.G.S. The Priory, Colleton-crescent, Exeter.
1890. *Villamil, Major R. de, R.E. Care of Messrs. Cox & Co., 16 Charing Cross, London, S.W.

Year of Election.

1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1883. *Vines, Sydney Howard, M.A., D.Sc., F.R.S., F.L.S., Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1856. ‡VIVIAN, EDWARD, M.A. Woodfield, Torquay.
*VIVIAN, Sir H. HUSSEY, Bart., M.P., F.G.S. Park Wern, Swansea; and 27 Belgrave-square, London, S.W.

1886. *Wackrill, Samuel Thomas, J.P. Leamington.
1860. ‡Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1890. §Wadsworth, George Henry. 3 Southfield-square, Bradford, Yorkshire.
1888. ‡Wadworth, H. A. Devizes, Wiltshire.
1890. §Wager, Harold W. T. 18 Consort-terrace, St. John's-road, Leeds.
1884. ‡Wait, Charles E., Professor of Chemistry in the University of Tennessee. Knoxville, Tennessee, U.S.A.
1886. ‡Waite, J. W. The Cedars, Bestcot, Walsall.
1879. *Wake, Bernard. Abbeyfield, Sheffield.
1870. ‡WAKE, CHARLES STANILAND. Welton, near Brough, East Yorkshire.
1884. ‡Waldstein, Charles, M.A., Ph.D. Cambridge.
1873. ‡Wales, James. 4 Mount Royd, Manningham, Bradford, Yorkshire.
1882. *Walkden, Samuel. The Thorne, Bexhill, near Hastings, Sussex.
1890. §Walker, A. T. Headingley, Leeds.
1885. ‡Walker, Mr. Baillie. 52 Victoria-street, Aberdeen.
1890. §Walker, Benjamin. Moor Allerton, Leeds.
1885. §Walker, Charles Clement, F.R.A.S. Lilleshall Old Hall, Newport, Shropshire.
1883. ‡Walker, Mrs. Emma. 14 Bootham-terrace, York.
1883. ‡Walker, E. R. Pagefield Ironworks, Wigan.
Walker, Frederick John. The Priory, Bathwick, Bath.
1883. ‡Walker, George. 11 Hamilton-square, Birkenhead, Liverpool.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1890. §Walker, Dr. James. 8 Windsor-terrace, Dundee.
1885. ‡WALKER, General J. T., C.B., R.E., LL.D., F.R.S., F.R.G.S. 13 Cromwell-road, London, S.W.
1866. *WALKER, JOHN FRANCIS, M.A., F.C.S., F.G.S., F.L.S. 45 Bootham, York.
1855. ‡WALKER, JOHN JAMES, M.A., F.R.S. 12 Denning-road, Hampstead, London, N.W.
1881. ‡Walker, John Sydenham. 83 Bootham, York.
1867. *Walker, Peter G. 2 Airlie-place, Dundee.
1886. *Walker, Major Philip Billingsley. Sydney, New South Wales.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1884. ‡Walker, Samuel. Woodbury, Sydenham Hill, London, S.E.
1888. §Walker, Sydney F. 195 Severn-road, Cardiff.
1887. ‡Walker, T. A. 15 Great George-street, London, S.W.
1883. ‡Walker, Thomas A. 66 Leyland-road, Southport.
Walker, William. 47 Northumberland-street, Edinburgh.
1881. *Walker, William. 14 Bootham-terrace, York.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, D.C.L., F.L.S., F.R.G.S. Corfe View, Parkstone, Dorset.
1883. *Wallace, George J. Hawthornbank, Dunfermline.
1887. *Waller, Augustus, M.D. Weston Lodge, 16 Grove End-road, London, N.W.
1862. ‡Wallich, George Charles, M.D., F.L.S., F.R.G.S. 26 Addison-road North, Notting Hill, London, W.
1886. ‡Walliker, Samuel. Grandale, Westfield-road, Edgbaston, Birmingham.

Year of Election.

1889. *Wallis, Arnold J., M.A. 4 Belvoir-terrace, Cambridge.
1883. ‡Wallis, Rev. Frederick. Caius College, Cambridge.
1884. ‡Wallis, Herbert. Redpath-street, Montreal, Canada.
1886. ‡Wallis, Whitworth. Westfield, Westfield-road, Edgbaston, Birmingham.
1883. ‡Walmesley, Oswald. Shevington Hall, near Wigan.
1887. ‡Walmsley, J. Winton, Patricroft, Manchester.
1883. ‡Walmsley, T. M. Clevelands, Chorley-road, Heaton, Bolton.
1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., F.R.S. Ealing, Middlesex, W.
1863. ‡Walters, Robert. Eldon-square, Newcastle-upon-Tyne.
1881. ‡Walton, Thomas, M.A. Oliver's Mount School, Scarborough.
1863. ‡Wanklyn, James Alfred. 7 Westminster-chambers, London, S.W.
1884. ‡Wanless, John, M.D. 88 Union-avenue, Montreal, Canada.
1887. ‡Ward, A. W., M.A., Litt.D., Principal of Owens College, Manchester.
1874. §Ward, F. D., J.P., M.R.I.A. Clonaver, Strandtown, Co. Down.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡WARD, H. MARSHALL, M.A., F.R.S., F.L.S., Professor of Botany in the Royal Indian Civil Engineering College, Cooper's Hill, Egham.
1890. §Ward, Alderman John. Moor Allerton House, Leeds.
1874. §Ward, John, F.S.A. Lenoxvale, Belfast.
1887. §WARD, JOHN, F.G.S. 23 Stafford-street, Longton, Staffordshire.
1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1880. *Ward, J. Wesney. Red House, Ravensbourne Park, Catford, S.E.
1884. *Ward, John William. Newstead, Halifax.
1883. ‡Ward, Thomas, F.C.S. Arnold House, Blackpool.
1887. ‡Ward, Thomas. Brookfield House, Northwich.
1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.
1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1884. §Wardwell, George J. Rutland, Vermont, U.S.A.
1887. *Waring, Richard S. Pittsburg, Pennsylvania, U.S.A.
1878. §WARINGTON, ROBERT, F.R.S., F.C.S. Harpenden, St. Albans, Herts.
1882. ‡Warner, F. W., F.L.S. 20 Hyde-street, Winchester.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1875. ‡Warren, Algernon. 6 Windsor-terrace, Clifton, Bristol.
1887. ‡WARREN, Major-General Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. Athenæum Club, London, S.W.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
1875. *Waterhouse, Lieut.-Colonel J. 40 Hamilton-terrace, London, N.W.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.
1881. §Watherston, E. J. 12 Pall Mall East, London, S.W.
1887. ‡Watkin, F. W. 46 Auriol-road, West Kensington, London, W.
1884. ‡Watson, A. G., D.C.L. The School, Harrow, Middlesex.
1886. *Watson, C. J. 34 Smallbrook-street, Birmingham.
1883. ‡Watson, C. Knight, M.A. Society of Antiquaries, Burlington House, London, W.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1882. ‡WATSON, Rev. H. W., D.Sc., F.R.S. Berkeswell Rectory, Coventry.
1887. ‡Watson, J. Beauchamp. Gilt Hall, Carlisle.
1884. ‡Watson, John. Queen's University, Kingston, Ontario, Canada.

Year of Election.

1889. ‡Watson, John, F.I.C. 19 Bloomfield-terrace, Gateshead.
1859. ‡WATSON, JOHN FORBES, M.A., M.D., F.L.S. India Museum, Exhibition-road, London, S.W.
1863. ‡Watson, Joseph. Bensham-grove, Gateshead.
1863. ‡Watson, R. Spence, LL.D., F.R.G.S. Bensham-grove, Gateshead.
1867. ‡Watson, Thomas Donald. 23 Cross-street, Finsbury, London, E.C.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. Analytical Laboratory, The Folds, Bolton.
1882. ‡Watt, Alexander. 89 Hartington-road, Sefton Park, Liverpool.
1884. ‡Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.
1869. ‡Watt, Robert B. E., F.R.G.S. Ashley-avenue, Belfast.
1888. ‡WATTS, B. H. 10 Rivers-street, Bath.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1884. *Watts, Rev. Robert R. Stourpaine Vicarage, Blandford.
1870. §Watts, William, F.G.S. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
1883. §Watts, W. W., M.A., F.G.S. Broseley, Shropshire.
1859. ‡Waugh, Edwin. New Brighton, near Liverpool.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1883. ‡Webb, George. 5 Tenterden-street, Bury, Lancashire.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
1890. §Webb, Sidney. 4 Park-village East, London, N.W.
1866. *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1886. §Webber, Major-General C. E., C.B. 17 Egerton-gardens, London, S.W.
1859. ‡Webster, John. Edgehill, Aberdeen.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.
1882. *Webster, Sir Richard Everard, Q.C., M.P. Hornton Lodge, Hornton-street, Kensington, London, S.W.
1889. *Webster, William, F.C.S. 50 Lee Park, Lee, Kent.
1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe. Karlsruhe.
1889. ‡Weeks, John G. Bedlington.
1890. §Weiss, F. Ernest, B.Sc., F.L.S. Birch Bank, Christchurch-road, Hampstead, London, N.W.
1886. ‡Weiss, Henry. Westbourne-road, Birmingham.
1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, London, S.W.
1876. *WELDON, W. F. R., M.A., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London.
1880. *Weldon, Mrs. 1 Hoe-villas, Elliot-street, Plymouth.
1881. ‡Wellcome, Henry S. First Avenue Hotel, Holborn, London, W.C.
1879. §WELLS, CHARLES A., A.I.E.E. Bridge House, Lewes.
1881. §Wells, Rev. Edward, B.A. West Dean Rectory, Salisbury.
1883. ‡Welsh, Miss. Girton College, Cambridge.
1887. *Welton, T. A. Rectory House-grove, Clapham, London, S.W.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
1881. *Wenlock, The Right Hon. Lord. 8 Great Cumberland-place, London, W.; and Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.

Year of Election.

1864. *Were, Anthony Berwick. Hensingham, Whitehaven, Cumberland.
1886. ‡Wertheimer, J., B.A., B.Sc., F.C.S. Merchant Venturers' School, Bristol.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, London, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1853. ‡West, Stephen. Hessle Grange, near Hull.
1882. §Westlake, Ernest, F.G.S. Fordingbridge, Hants.
1882. ‡Westlake, Richard. Portswood, Southampton.
1863. ‡*Westmacott, Percy. Whickham, Gateshead, Durham.*
1875. *Weston, Sir Joseph D. Dorset House, Clifton Down, Bristol.
1860. ‡WESTWOOD, JOHN O., M.A., F.L.S., Professor of Zoology in the University of Oxford. Oxford.
1882. §WETHERED, EDWARD, F.G.S. 5 Berkeley-place, Cheltenham.
1884. ‡Wharton, E. R., M.A. 4 Broad-street, Oxford.
1885. *WHARTON, Captain W. J. L., R.N., F.R.S., F.R.G.S. Florys, Prince's-road, Wimbledon Park, Surrey.
1888. ‡Wheatcroft, William G. 6 Widcombe-terrace, Bath.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N.W.
1884. ‡Wheeler, Claude L. 123 Metcalfe-street, Montreal, Canada.
1883. *Wheeler, George Brash. Elm Lodge, Wickham-road, Beckenham, Kent.
1878. *Wheeler, W. H., M.Inst.C.E. Boston, Lincolnshire.
1888. §Whelen, John Leman. 73 Fellows-road, London, N.W.
1883. ‡Whelpton, Miss K. Newnham College, Cambridge.
1888. *Whidborne, Miss Alice Maria. Charanté, Torquay.
1888. *Whidborne, Miss Constance Mary. Charanté, Torquay.
1879. *WHIDBORNE, Rev. GEORGE FERRIS, M.A., F.G.S. St. George's Vicarage, Battersea Park-road, London, S.W.
1873. ‡Whipple, George Matthew, B.Sc., F.R.A.S. Kew Observatory, Richmond, Surrey.
1884. ‡Whischer, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1887. ‡*Whitaker, E. J. Burnley, Lancashire.*
1874. ‡Whitaker, Henry, M.D. 33 High-street, Belfast.
1883. *Whitaker, T. Saville Heath, Halifax.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.; and 33 East Park-terrace, Southampton.
1886. ‡Whitcombe, E. B. Borough Asylum, Winson Green, Birmingham.
1886. ‡White, Alderman, J.P. Sir Harry's-road, Edgbaston, Birmingham.
1876. ‡White, Angus. Easdale, Argyllshire.
1886. ‡White, A. Silva, F.R.G.S., Secretary to the Royal Scottish Geographical Society, Edinburgh.
1883. ‡White, Charles. 23 Alexandra-road, Southport.
1882. ‡White, Rev. George Cecil, M.A. Nutshalling Rectory, Southampton.
1885. *White, J. Martin. Spring Grove, Dundee.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
1859. ‡WHITE, JOHN FORBES. 311 Union-street, Aberdeen.
1883. ‡White, John Reed. Rossall School, near Fleetwood.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1869. ‡*White, Laban. Blandford, Dorset.*
1884. ‡White, R. 'Gazette' Office, Montreal, Canada.
1859. ‡White, Thomas Henry. Tandragee, Ireland.

Year of Election.

1877. *White, William. 9 The Paragon, Blackheath, London, S.E.
1883. *White, Mrs. 9 The Paragon, Blackheath, London, S.E.
1886. §White, William. The Ruskin Museum, Sheffield.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. *Whitehead, Peter Ormerod. 99 New John-street West, Birmingham.
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1855. *Whitehouse, Wildeman W. O. 18 Salisbury-road, West Brighton.
1871. ‡Whitelaw, Alexander. 1 Oakley-terrace, Glasgow.
1884. ‡Whiteley, Joseph. Huddersfield.
1881. ‡Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1866. ‡Whitfield, Samuel. Eversfield, Eastnor-grove, Leamington.
1852. ‡Whitla, Valentine. Beneden, Belfast.
Whitley, Rev. Canon C. T., M.A., F.R.A.S. Bedlington Vicarage, Northumberland.
1857. *Whitty, Rev. John Irwine, M.A., D.C.L., LL.D. 40 Kingswood-road, Penge, London, S.E.
1887. ‡Whitwell, William. Overdene, Saltburn-by-the-Sea.
1874. *Whitwill, Mark. Redland House, Bristol.
1883. ‡Whitworth, James. 88 Portland-street, Southport.
1870. ‡Whitworth, Rev. W. Allen, M.A. Glenthorne-road, Hammersmith, London, W.
1888. ‡Wickham, Rev. F. D. C. Horsington Rectory, Bath.
1865. ‡Wiggin, Henry, M.P. Metchley Grange, Harborne, Birmingham.
1886. ‡Wiggin, Henry A. The Lea, Harborne, Birmingham.
1885. ‡Wigglesworth, Alfred. Gordondale House, Aberdeen.
1883. ‡Wigglesworth, Mrs. New Parks House, Falsgrave, Scarborough.
1881. *Wigglesworth, Robert. Beckwith Knowle, near Harrogate.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1883. ‡Wigner, G. W. Plough-court, 37 Lombard-street, London, E.C.
1889. *Wilberforce, L. R., M.A. Trinity College, Cambridge.
1881. ‡Wilberforce, W. W. Fishergate, York.
1887. ‡Wild, George. Bardsley Colliery, Ashton-under-Lyne.
1887. *Wilde, Henry, F.R.S. The Hurst, Alderley Edge, Manchester.
1887. ‡Wilkinson, C. H. Slaithwaite, near Huddersfield.
1890. §Wilkinson, C. S., F.G.S., F.L.S., Government Geologist. Sydney, New South Wales.
1857. ‡Wilkinson, George. Temple Hill, Killiney, Co. Dublin.
1886. *Wilkinson, J. H. Corporation-street, Birmingham.
1879. ‡Wilkinson, Joseph. York.
1887. *Wilkinson, Thomas Read. The Polygon, Ardwick, Manchester.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1869. §Wilks, George Augustus Frederick, M.D. Stanbury, Torquay.
1890. §Willans, J. W. Kirkstall, Leeds.
1859. ‡Willet, John, M.Inst.C.E. 35 Albyn-place, Aberdeen.
1872. ‡Willett, Henry, F.G.S. Arnold House, Brighton.
1861. *Williams, Charles Theodore, M.A., M.B. 2 Upper Brook-street, Grosvenor-square, London, W.
1887. ‡Williams, E. Leader, M.Inst.C.E. The Oaks, Altrincham.
1883. *Williams, Edward Starbuck. Ty-ar-y-graig, Swansea.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 1 Gorse-lane, Swansea.
1875. **Williams, Rev. Herbert A., M.A. S.P.G. College, Trichinopoly, India.*
1883. ‡Williams, Rev. H. A. The Ridgeway, Wimbledon, Surrey.
1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1888. ‡Williams, James. Bladud Villa, Entryhill, Bath.
1887. ‡Williams, J. Francis, Ph.D. Salem, New York, U.S.A.

Year of Election.

1888. *Williams, Miss Katherine. Llandaff House, Pembroke-vale, Clifton, Bristol.
1875. *Williams, M. B. Killay House, near Swansea.
1879. ‡WILLIAMS, MATTHEW W., F.C.S. Queenwood College, Stockbridge, Hants.
1886. ‡Williams, Richard, J.P. Brunswick House, Wednesbury.
1883. ‡Williams, R. Price. North Brow, Primrose Hill, London, N.W.
1883. §Williams, T. H. 2 Chapel-walk, South Castle-street, Liverpool.
1883. §Williams, T. Howell. 58 Lady Margaret-road, London, N.W.
1888. ‡Williams, W. Cloud House, Stapleford, Nottinghamshire.
1877. *WILLIAMS, W. CARLETON, F.C.S. Firth College, Sheffield.
1865. ‡Williams, W. M. Stonebridge Park, Willesden.
1883. ‡Williamson, Miss. Sunnybank, Ripon, Yorkshire.
1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., LL.D., D.C.L., F.R.S., F.C.S., Corresponding Member of the French Academy. (GENERAL TREASURER.) 17 Buckingham-street, London, W.C.
1857. ‡WILLIAMSON, BENJAMIN, M.A., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
WILLIAMSON, WILLIAM C., LL.D., F.R.S., Professor of Botany in Owens College, Manchester. 4 Egerton-road, Fallowfield, Manchester.
1889. ‡Willis, James. 14 Portland-terrace, Newcastle-upon-Tyne.
1883. ‡*Willis, T. W.* 51 *Stanley-street, Southport.*
1882. ‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.
1859. *Wills, The Hon. Sir Alfred. Clive House, Esher, Surrey.
1886. ‡Wills, A. W. Wylde Green, Erdington, Birmingham.
1886. ‡Wilson, Alexander B. Holywood, Belfast.
1885. ‡Wilson, Alexander H. 2 Albyn-place, Aberdeen.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. 124 Bothwell-street, Glasgow.
1859. ‡Wilson, Alexander Stephen. North Kinmundy, Summerhill, by Aberdeen.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1874. ‡WILSON, Colonel Sir C. W., R.E., K.C.B., K.C.M.G., D.C.L., F.R.S., F.R.G.S. Ordnance Survey Office, Southampton.
1850. ‡Wilson, Sir Daniel. Toronto, Canada.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1890. §Wilson, Edmund. Denison Hall, Leeds.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 73 Newman-street, Oxford-street, London, W.
1885. §Wilson, Brigade-Surgeon G. A. 4 St. Margaret's-terrace, Cheltenham.
1875. ‡Wilson, George Fergusson, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1883. *Wilson, Henry, M.A. Eastnor, Malvern Link, Worcestershire.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1885. ‡Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
1886. ‡Wilson, J. E. B. Woodslee, Wimbledon, Surrey.
1890. §Wilson, J. Mitchell, M.D. Hall Gate, Doncaster.
1865. ‡WILSON, Rev. JAMES M., M.A., F.G.S. Clifton College, Bristol.
1884. ‡Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1858. *Wilson, John. Seacroft Hall, near Leeds.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.

Year of Election.

1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1861. ‡Wilson, Thos. Bright. 4 Hope View, Fallowfield, Manchester.
1887. §Wilson, W., jun. Hillock, Terpersie, by Alford, Aberdeenshire.
1871. *Wilson, William E. Daramona House, Rathowen, Ireland.
1861. *Wiltshire, Rev. Thomas, M.A., F.G.S., F.L.S., F.R.A.S., Assistant Professor of Geology and Mineralogy in King's College, London. 25 Granville-park, Lewisham, London, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1886. §Windle, Bertram C. A., M.A., M.D., Professor of Anatomy in Queen's College, Birmingham.
1887. ‡Windsor, William Tessimond. Sandiway, Ashton-on-Mersey.
1886. ‡*Winter, George W. 55 Wheeley's-road, Edgbaston, Birmingham.*
1863. *Winwood, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1888. ‡Wodehouse, E. R., M.P. 56 Chester-square, London, S.W.
1883. ‡Wolfenden, Samuel. Cowley Hill, St. Helens, Lancashire.
1884. ‡Womack, Frederick, Lecturer on Physics and Applied Mathematics at St. Bartholomew's Hospital. 68 Abbey-road, London, N.W.
1881. *Wood, Alfred John. 5 Cambridge-gardens, Richmond, Surrey.
1883. §Wood, Mrs. A. J. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.
1883. ‡Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.
1875. *Wood, George William Rayner. Singleton, Manchester.
1878. §Wood, Sir H. Trueman, M.A. Society of Arts, John-street, Adelphi, London, W.C.
1883. *Wood, James, LL.D. Grove House, Scarisbrick-street, Southport.
1881. §Wood, John, B.A., F.R.A.S. Wharfedale College, Boston Spa, Yorkshire.
1883. *Wood, J. H. Woodbine Lodge, Scarisbrick New-road, Southport.
1886. ‡Wood, Rev. Joseph. Carpenter-road, Birmingham.
1883. ‡Wood, Mrs. Mary. Ellison-place, Newcastle-on-Tyne.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1890. *Wood, Robert H., M.Inst.M.E. 15 Bainbrigge-road, Headingley, Leeds.
1871. ‡Wood, Provost T. Barleyfield, Portobello, Edinburgh.
1850. ‡Wood, Rev. Walter. Elie, Fife.
1865. *Wood, William, M.D. 99 Harley-street, London, W.
1872. §Wood, William Robert. Carlisle House, Brighton.
*Wood, Rev. William Spicer, M.A., D.D. Higham, Rochester.
1863. *Woodall, John Woodall, M.A., F.G.S. St. Nicholas House, Scarborough.
1884. ‡Woodbury, C. J. H. 31 Devonshire-street, Boston, U.S.A.
1883. ‡Woodcock, Herbert S. The Elms, Wigan.
1884. ‡Woodcock, T., M.A. 150 Cromwell-road, London, S.W.
1884. ‡Woodd, Arthur B. Woodlands, Hampstead, London, N.W.
1850. *Woodd, Charles H. L., F.G.S. Roslyn House, Hampstead, London, N.W.
1888. *Woodiwiss, Alfred. Belair, Trafalgar-road, Birkdale, Southport.
1888. *Woodiwiss, Mrs. Alfred. Belair, Trafalgar-road, Birkdale, Southport.
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
*Woods, Edward, M.Inst.C.E. 6b Victoria-street, Westminster, London, S.W.
1883. ‡Woods, Dr. G. A., F.R.S.E., F.R.M.S. Carlton House, 57 Hoghton-street, Southport.

Year of Election.

Woods, Samuel. 1 Drapers'-gardens, Throgmorton-street, London, E.C.
1888. ‡Woodthorpe, Colonel. Messrs. King & Co., 45 Pall Mall, London, S.W.
1887. *Woodward, Arthur Smith, F.G.S., F.L.S. 183b King's-road, Chelsea, London, S.W.
*Woodward, C. J., B.Sc. 97 Harborne-road, Birmingham.
1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, London, S.W.
1866. ‡Woodward, Henry, LL.D., F.R.S., F.G.S., Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, London, S.W.
1870. ‡Woodward, Horace B., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1881. ‡Wooler, W. A. Sadberge Hall, Darlington.
1884. *Woolcock, Henry. Rickerby House, St. Bees.
1890. §Woollcombe, Robert Lloyd, LL.D., F.S.S., M.R.I.A. 14 Waterloo-road, Dublin.
1877. ‡Woollcombe, Surgeon-Major Robert W. 14 Acre-place, Stoke, Devonport.
1883. *Woolley, George Stephen. 69 Market-street, Manchester.
1856. ‡Woolley, Thomas Smith, jun. South Collingham, Newark.
1874. ‡Workman, Charles. Ceara, Windsor, Belfast.
1878. ‡Wormell, Richard, M.A., D.Sc. Roydon, near Ware, Hertfordshire.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. Stourbridge, Worcestershire.
Worthington, James. Sale Hall, Ashton-on-Mersey.
1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, London, N.W.
1884. ‡Wragge, Edmund. 109 Wellesley-street, Toronto, Canada.
1879. ‡Wrentmore, Francis. 34 Holland Villas-road, Kensington, London, S.W.
1883. *Wright, Rev. Arthur, M.A. Queen's College, Cambridge.
1883. *Wright, Rev. Benjamin, M.A. Sandon Rectory, Chelmsford.
1890. §Wright, Dr. C. J. Virginia-road, Leeds.
1871. §Wright, C. R. A., D.Sc., F.R.S., F.C.S., Lecturer on Chemistry in St. Mary's Hospital Medical School, Paddington, London, W.
1861. *Wright, E. Abbot. Castle Park, Frodsham, Cheshire.
1857. ‡Wright, E. Perceval, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1886. ‡Wright, Frederick William. 4 Full-street, Derby.
1884. ‡Wright, Harrison. Wilkes' Barré, Pennsylvania, U.S.A.
1876. ‡Wright, James. 114 John-street, Glasgow.
1874. ‡*Wright, Joseph. Cliftonville, Belfast.*
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
1884. ‡Wright, Professor R. Ramsay, M.A., B.Sc. University College, Toronto, Canada.
Wright, T. G., M.D. Milnes House, Wakefield.
1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.
1871. ‡Wrightson, Thomas, M.Inst.C.E., F.G.S. Norton Hall, Stockton-on-Tees.
1887. ‡Wrigley, Rev. Dr., M.A., M.D., F.R.A.S. 15 Gauden-road, London, S.W.
1876. ‡Wunsch, Edward Alfred, F.G.S. Carharrack, Scorrier, Cornwall.
1867. ‡Wylie, Andrew. Prinlaws, Fifeshire.

Year of Election.

1883. ‡Wyllie, Andrew. 10 Park-road, Southport.
1885. ‡Wyness, James D., M.D. 53 School-hill, Aberdeen.
1871. ‡Wynn, Mrs. Williams. Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S. Geological Survey Office, 14 Hume-street, Dublin.

1875. ‡Yabbicom, Thomas Henry. 37 White Ladies-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1865. ‡Yates, Edwin. Stonebury, Edgbaston, Birmingham.
1883. §Yates, James. Public Library, Leeds.
1867. ‡Yeaman, James. Dundee.
1887. ‡Yeats, Dr. Chepstow.
1884. ‡Yee, Fung. Care of R. E. C. Fittock, Esq., Shanghai, China.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1884. ‡York, Frederick. 87 Lancaster-road, Notting Hill, London, W.
1886. *YOUNG, A. H., M.B., F.R.C.S., Professor of Anatomy in Owens College, Manchester.
1884. ‡Young, Frederick. 5 Queensberry-place, London, S.W.
1884. ‡Young, Professor George Paxton. 121 Bloor-street, Toronto, Canada.
1876. ‡YOUNG, JOHN, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.
1885. ‡Young, R. Bruce. 8 Crown-gardens, Dowanhill, Glasgow.
1886. §Young, R. Fisher. New Barnet, Herts.
1883. *YOUNG SYDNEY, D.Sc., Professor of Chemistry in University College, Bristol.
1887. §Young, Sydney. 29 Mark-lane, London, E.C.
1890. §Young, T. Graham, F.R.S.E. Westfield, West Calder, Scotland.
1868. ‡Youngs, John. Richmond Hill, Norwich.
1876. ‡*Yuille, Andrew. 7 Sardinia-terrace, Hillhead, Glasgow.*

1886. ‡Zair, George. Arden Grange, Solihull, Birmingham.
1886. ‡Zair, John. Merle Lodge, Moseley, Birmingham.

CORRESPONDING MEMBERS.

Year of Election.

1871. HIS IMPERIAL MAJESTY THE EMPEROR OF THE BRAZILS.
1887. Cleveland Abbe. Weather Bureau of the Army Signal Office, Washington, United States.
1881. Professor G. F. Barker. University of Pennsylvania, Philadelphia, United States.
1870. Professor Van Beneden, LL.D. Louvain, Belgium.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 14, 4, Germany.
1880. Professor Ludwig Boltzmann. Halbärtgasse, 1, Gratz, Austria.
1887. His Excellency R. Bonghi. Rome.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, United States.
1884. Professor H. P. Bowditch, M.D. Boston, Massachusetts, United States.
1890. Professor Brentano. Leipzig.
1884. Professor George J. Brush. Yale College, New Haven, United States.
1887. Professor J. W. Bruhl. Freiburg.
1887. Professor G. Capellini. Royal University of Bologna.
1887. Professor J. B. Carnoy. Louvain.
1887. H. Caro. Mannheim.
1861. Dr. Carus. Leipzig.
1887. F. W. Clarke. United States Geological Survey, Washington, United States.
1855. Dr. Ferdinand Cohn. Breslau, Prussia.
1881. Professor Josiah P. Cooke. Harvard University, United States.
1873. Professor Guido Cora. 74 Corso Vittorio Emanuele, Turin.
1880. Professor Cornu. L'École Polytechnique, Paris.
1870. J. M. Crafts, M.D. L'École des Mines, Paris.
1876. Professor Luigi Cremona. The University, Rome.
1889. W. H. Dall. United States Geological Survey, Washington, United States.
1862. Wilhelm Delffs, Professor of Chemistry in the University of Heidelberg.
1864. M. Des Cloizeaux. Rue Monsieur, 13, Paris.
1872. Professor G. Dewalque. Liége, Belgium.
1890. Professor V. Dwelshauvers-Dery. Liége.
1870. Dr. Anton Dohrn. Naples.
1876. Professor Alberto Eccher. Florence.
1874. Dr. W. Feddersen. Leipzig.
1886. Dr. Otto Finsch. Bremen.
1887. Professor R. Fittig. Strasburg.
1872. W. de Fonvielle. 50 Rue des Abbesses, Paris.

Year of Election.

1856. Professor E. Frémy. L'Institut, Paris.
1887. Dr. Anton Fritsch. Prague.
1881. *C. M. Gariel, Secretary of the French Association for the Advancement of Science. 4 Rue Antoine Dubois, Paris.*
1866. Dr. Gaudry. Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1884. Professor J. Willard Gibbs. Yale College, New Haven, United States.
1884. Professor Wolcott Gibbs. Harvard University, Cambridge, Massachusetts, United States.
1889. G. K. Gilbert. United States Geological Survey, Washington, United States.
1870. William Gilpin. Denver, Colorado, United States.
1889. Professor Gustave Gilson. Louvain.
1889. A. Gobert. 214 Chaussée de Charleroi, Brussels.
1876. Dr. Benjamin A. Gould. Cambridge, Massachusetts, United States.
1884. Major A. W. Greely. Washington, United States.
1862. Dr. D. Bierens de Haan, Member of the Royal Academy of Sciences, Amsterdam. Leiden, Holland.
1876. Professor Ernst Haeckel. Jena.
1889. Horatio Hale. Clinton, Ontario, Canada.
1881. Dr. Edwin H. Hall. Baltimore, United States.
1872. Professor James Hall. Albany, State of New York.
1889. Dr. Max von Hantken. Budapesth.
1887. Fr. von Hefner-Alteneck. Berlin.
1877. Professor H. L. F. von Helmholtz. Berlin.
1872. J. E. Hilgard, Assist.-Supt. U.S. Coast Survey. Washington, United States.
1887. Professor W. His. Leipzig.
1887. S. Dana Horton. New York.
1881. Professor A. A. W. Hubrecht, LL.D., C.M.Z.S. Utrecht.
1887. Dr. Oliver W. Huntington. Harvard University, Cambridge, Massachusetts, United States.
1884. Professor C. Loring Jackson. Harvard University, Cambridge, Massachusetts, United States.
1867. Dr. Janssen, LL.D. The Observatory, Meudon, Seine-et-Oise.
1876. Dr. W. J. Janssen. Villa Frisia, Aroza, Graubünden, Switzerland.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy. Annapolis, United States.
1887. Professor C. Julin. Liége.
1876. Dr. Giuseppe Jung. 7 Via Principe Umberto, Milan.
1877. M. Akin Kàroly. 92 Rue Richelieu, Paris.
1862. Aug. Kekulé, Professor of Chemistry. Bonn.
1884. Professor Dairoku Kikuchi, M.A. Imperial University, Tokio, Japan.
1873. Dr. Felix Klein. The University, Leipzig.
1874. Dr. Knoblauch. Halle, Germany.
1856. Professor A. Kölliker. Wurzburg, Bavaria.
1887. Professor Dr. Arthur König. Physiological Institute, University, Berlin.
1887. Professor Krause. Göttingen.
1877. Dr. Hugo Kronecker, Professor of Physiology. The University, Bern, Switzerland.
1887. Lieutenant R. Kund. German African Society, Berlin.
1887. Professor A. Ladenburg. Kiel.
1887. Professor J. W. Langley. Michigan, United States.
1882. Professor S. P. Langley, LL.D., Secretary of the Smithsonian Institution. Washington, United States.

Year of Election.

1887. Professor Count von Laubach. Göttingen.
1887. Dr. Leeds, Professor of Chemistry at the Stevens Institute, Hoboken, New Jersey, United States.
1872. M. Georges Lemoine. 76 Rue d'Assas, Paris.
1887. Professor A. Lieben. Vienna.
1883. Dr. F. Lindemann, Professor of Mathematics in the University of Königsberg.
1877. Dr. M. Lindemann, Hon. Sec. of the Bremen Geographical Society. Bremen.
1887. *Professor G. Lippmann. Paris.*
1887. Dr. Georg Lunge. Zurich.
1871. Professor Jacob Lüroth. The University, Freiburg, Germany.
1871. Dr. Lütken. Copenhagen.
1887. Dr. Henry C. McCook. Philadelphia, United States.
1867. Professor Mannheim. Rue de la Pompe, 11, Passy, Paris.
1881. Professor O. C. Marsh. Yale College, New Haven, United States.
1867. Professor Ch. Martins, Director of the Jardin des Plantes. Montpellier, France.
1887. Dr. C. A. Martius. Berlin.
1890. Professor E. Mascart, Membre de l'Institut. Paris.
1887. Professor D. Mendeléef. St. Petersburg.
1887. Professor N. Menschutkin. St. Petersburg.
1887. Professor Lothar Meyer. Tübingen.
1884. Albert A. Michelson. Cleveland, Ohio, United States.
1848. Professor J. Milne-Edwards. Paris.
1887. Dr. Charles Sedgwick Minot. Boston, Massachusetts, United States.
1877. Professor V. L. Moissenet. L'École des Mines, Paris.
1864. Dr. Arnold Moritz. The University, Dorpat, Russia.
1887. E. S. Morse. Peabody Academy of Science, Salem, Massachusetts, United States.
1889. Dr. F. Nansen. Christiania.
1866. *Chevalier C. Negri, President of the Italian Geographical Society. Turin, Italy.*
1864. Herr Neumayer. Deutsche Seewarte, Hamburg.
1884. Professor Simon Newcomb. Washington, United States.
1869. Professor H. A. Newton. Yale College, New Haven, United States.
1887. Professor Noelting. Mühlhausen, Elsass.
1890. Professor W. Ostwald. Leipzig.
1889. Professor A. S. Packard. Brown University, Providence, Rhode Island, United States.
1890. Maffeo Pantaleoni, Director of the Royal Superior School of Commerce. Bari.
1887. Dr. Pauli. Höchst-on-Main, Germany.
1890. Professor Otto Pettersson. Stockholm.
1857. Gustave Plarr, D.Sc. 22 Hadlow-road, Tunbridge, Kent.
1870. Professor Felix Plateau. 64 Boulevard du Jardin Zoologique, Gand.
1884. Major J. W. Powell, Director of the Geological Survey of the United States. Washington, United States.
1887. Professor W. Preyer. The University, Berlin.
1887. N. Pringsheim. Berlin.
1886. Professor Putnam, Secretary of the American Association for the Advancement of Science. Harvard University, Cambridge, Massachusetts, United States.
1887. Professor G. Quincke. Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich
1886. Rev. A. Renard. Royal Museum, Brussels.

Year of Election.

1872. Professor Victor von Richter. Victoria-strasse, 9, Breslau.
1873. Baron von Richthofen. The University, Leipzig.
1887. Dr. C. V. Riley. Washington, United States.
1866. F. Römer, Ph.D., Professor of Geology and Palæontology in the University of Breslau. Breslau, Prussia.
1890. A. Lawrence Rotch. Boston, Massachusetts, United States.
1881. Professor Henry A. Rowland. Baltimore, United States.
1887. M. le Marquis de Saporta. Aix-en-Provence, Bouches du Rhône.
1857. Baron Herman de Schlagintweit-Sakünlünski. Jaegersberg Castle, near Forchheim, Bavaria.
1883. Dr. Ernst Schröder. Karlsruhe, Baden.
1874. Dr. G. Schweinfurth. Cairo.
1846. Baron de Selys-Longchamps. Liége, Belgium.
1872. Professor Carl Semper. Wurzburg, Bavaria.
1873. Dr. A. Shafarik. Prague.
1861. Dr. Werner von Siemens. Berlin.
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1876. Professor R. D. Silva. L'École Centrale, Paris.
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1888. Dr. Alfred Springer. Cincinnati, Ohio, United States.
1866. Professor Steenstrup. Copenhagen.
1889. Professor G. Stefanescu. Bucharest.
1881. Dr. Cyparissos Stephanos. The University, Athens.
1881. Professor Sturm. Münster, Westphalia.
1871. Dr. Joseph Szabó. Pesth, Hungary.
1870. Professor Tchebichef, Membre de l'Académie de St. Pétersbourg.
1884. Professor Robert H. Thurston. Sibley College, Cornell University, Ithaca, New York, United States.
1864. Dr. Otto Torell, Professor of Geology in the University of Lund, Sweden.
1887. Dr. T. M. Treub. Java.
1887. Professor John Trowbridge. Harvard University, Cambridge, Massachusetts, United States.
Arminius Vámbéry, Professor of Oriental Languages in the University of Pesth, Hungary.
1890. Professor J. H. Van't Hoff. Amsterdam.
1889. *Wladimir Vernadsky, Keeper of the Mineralogical Museum, University of St. Petersburg.*
1887. Professor John Vilanova. Madrid.
1886. M. Jules Vuylsteke. 80 Rue de Lille, Menin, Belgium.
1887. Professor H. F. Weber. Zurich.
1887. Professor L. Weber. Breslau.
1887. Professor August Weismann. Freiburg.
1887. Dr. H. C. White. Athens, Georgia, United States.
1881. Professor H. M. Whitney. Beloit College, Wisconsin, United States.
1874. Professor G. Wiedemann. Leipzig.
1887. Professor E. Wiedemann. Leipzig.
1887. Professor R. Wiedersheim. Freiburg.
1887. Professor J. Wislicenus. Leipzig.
1887. Dr. Otto N. Witt. 33 Lindenallée, Westend-Charlottenburg, Berlin.
1887. *Dr. Ludwig H. Wolf. Leipzig.*
1876. Professor Adolph Wüllner. Aix-la-Chapelle.
1887. Professor C. A. Young. Princeton College, United States.
1887. Professor F. Zirkel. Leipzig.

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